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University — Université: University of Alberta

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée: Master of Science in Plant Breeding

Year this degree conferred — Année d'obtention de ce grade: 1983

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CROP GROWTH ANALYSIS OF RAPESEED (*BRASSICA NAPUS* L., SUMMER-TYPE, AND *B. CAMPESTRIS* L., SUMMER-TYPE)

by

(C)

GAYLERDE REUBEN KASA

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

PLANT BREEDING

DEPARTMENT OF PLANT SCIENCE

EDMONTON, ALBERTA

FALL, 1983

THE UNIVERSITY OF ALBERTA

RELEASE FORM

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TITLE OF THESIS CROP GROWTH ANALYSIS OF RAPESEED (*BRASSICA NAPUS* L., SUMMER-TYPE, AND *B. CAMPESTRIS* L., SUMMER-TYPE)

DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED FALL, 1983

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ABSTRACT

A quantitative analysis of the growth, development and yield of three genotypes of *Brassica napus* L. summer-type in 1979, and eight genotypes of *B. napus* L. and two genotypes of *B. campestris* L. in 1980, were determined from field experiments conducted in central Alberta.

B. campestris L. reached all growth stages, except onset of stem elongation, significantly earlier than *B. napus* L. and correspondingly had a significantly shorter stem elongation period and seed formation period. *B. campestris* L. had significantly higher leaf emergence rates during all growth periods. *B. napus* L. had significantly greater crop dry weight at first flower and fifteen days after first flower and significantly greater mean crop growth rate from seeding to first flower. Mean relative growth rates were significantly higher in *B. napus* L. than *B. campestris* L. during all growth periods. *B. napus* L. had significantly greater leaf area index at first flower and fifteen days after first flower, significantly greater axillary branch leaf area index at first flower, significantly greater leaf area duration from first flower to maturity of first pod, and significantly greater axillary branch leaf area duration from first flower to maturity of first pod than *B. campestris* L.

Late maturing genotypes of *B. napus* L. had significantly higher leaf emergence rates during all growth periods than did the earlier maturing genotypes, but were significantly later in reaching first axillary branch leaf, first flower, first true leaf senesced and end of true leaves. This study confirmed other studies which indicated "number of days to first flower" as a major factor in determining the time to maturity in both annual rapeseed species. Earlier maturing genotypes of *B. napus* L. had significantly greater mean leaf area ratios from seeding to first flower, axillary branch leaf area duration, and mean relative growth rates over all growth periods. Late maturing genotypes had significantly greater mean unit leaf rate from seeding to first flower, crop dry weight at first flower and fifteen days after first flower, mean crop growth rates over all growth periods and greater leaf area index at first flower and fifteen days after first flower. The significantly greater axillary branch leaf area durations of earlier maturing genotypes of *B. napus* L. is advantageous since it coincides with seed filling and the axillary branch leaves are located in close proximity to the seeds.

The usefulness of mean relative growth rate as a selection tool in breeding programs warrants further study. Given the greater growth efficiency of earlier maturing genotypes, they could be more productive at higher seeding rates than genotypes which are not as efficient.

ACKNOWLEDGEMENTS

Sincere thanks to Dr. Z.P. Kondra who provided me with the opportunity for graduate study and gave direction and suggestions throughout the study.

Sincere thanks are also due to field and laboratory staff (especially Del, Francis, Robert, Dallas, Sue, Mary, and Jill) who helped make the completion of this study possible.

Special thanks to my wife, Bernadette, to my mother and father, and other family members for their assistance and encouragement.

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I. INTRODUCTION

Rapeseed has become a viable alternative to cereal production on the Canadian prairies. The importance of rapeseed as a commercial crop in Canada began in 1942 in response to war-time demands for industrial oil (Downey and Bolton, 1961). Since 1942, when 44,000 bushels were produced on 1300 hectares (Perkins, 1976), the rapeseed acreage has expanded rapidly, reaching 2.1 million hectares in 1980 (Prairie Grain Variety Survey, 1980). At present, 60% of the rapeseed acreage in western Canada is *Brassica napus* L. *forma annua* (i.e. summer-type (S.T.)) and 40% is *B. campestris* L. *forma annua*. Although *B. napus* L. matures 10 - 14 days later than *B. campestris* L., it offers a superior 'quality package' and is also higher yielding. Recent development of the high yielding, early maturing cultivar 'Altex', has increased the percentage of rapeseed acreage in Alberta sown to *B. napus* L. from 19% in 1979 to 38% in 1980 (Prairie Grain Variety Survey, 1980).

The primary factors leading to the acceptance and rapid increase in rapeseed utilization has been the improvement in processing methods and the ability of plant breeders to respond to regulations imposed on the quality of the oil and meal. "Canola" is the term now registered by the Western Canadian Oilseed Crushers Association for reference to seed and seed products with 5% or less erucic acid and three milligrams per gram or less normally measured glucosinolates (Adolphe, 1979). Rapeseed oil was approved for human use under the Food and Drug regulations of Canada in 1958 (Degenhardt, 1979), and has found its primary use in cooking oils, margarines and salad dressings. Cooperative research on many aspects of rapeseed processing and utilization has resulted in rapeseed oil becoming the most widely used edible oil in Canada. In 1980, canola oil accounted for approximately 47% of the deodorized vegetable oil production in Canada (Statistics Canada, 1980). Rapeseed meal that is low in glucosinolates and high in protein can be used in livestock feed supplements.

Canada is the world's leading rapeseed exporter. The presence of a domestic rapeseed crushing industry has done much to stabilize market conditions. Significant domestic crushing was initiated about 1956, when rapeseed was first crushed as an edible oil product in Canada (Perkins, 1976). Currently, with six crushing plants operating, the Canadian rapeseed processing industry has the capacity to crush 3450 tons per day (41.5 million bushels annually) (Degenhardt, 1979).

In order for a crop cultivar to be attractive to farmers, assuming all other variables are equal, it must be high yielding. In the past, the attention of plant breeders has centred on 'final' characters (i.e. yield components), rather than on the development by which final characters are reached (Allard and Bradshaw, 1964). The present emphasis in plant breeding methods is described by Thurling (1974);

> "Significant improvements in crop yield have been obtained through breeding, despite a limited

> understanding of how yield is inherited or of what physiological characteristics of the plant determine potential yield. At the present time, however, it is recognized that a reassessment of traditional breeding methods based on information from biometrical and physiological studies of crop yield is essential if further worthwhile gains in the yielding capacity of a number of crop plants are to be achieved. Such reassessments have prompted proposals regarding improved methods of generating and manipulating genetic variation in breeding populations, as well as considerations of new selection criteria based on physiological characters. Although these reappraisals of breeding methods have been largely confined to intensively bred crops in which declining selection responses have been a cause for some concern, the underlying principles are pertinent to any crop improvement program."

It is possible to alter growth characteristics of *B. napus* L. to produce increased seed yield (Campbell *et al*., 1978). In Canada and Australia the major aim in research is improvement in yield through selection for better adaptation to the local environment, which includes identification of an optimal developmental pattern. As an example in *B. napus* L., the generally accepted genetic association between late maturity and high seed yield can be broken by appropriate breeding and selection (Degenhardt and Kondra, 1981a). Although data from cultivar comparisons indicate that physiological analyses of yield should prove useful in breeding programs, present analytical techniques are such as to preclude widespread use of photosynthetic and translocation measurements as a means of screening large breeding populations (Thurling, 1974).

The objective of this study was to analyze quantitatively the growth, development and yield of a wide range of genotypes of *B. napus* L. and *B. campestris* L. and apply the concepts of "Plant Growth Analysis". This research approach may provide physiological plant breeding criteria and additional information enabling manipulation of the crop's environment to its best advantage.

II. LITERATURE REVIEW

Cultivars developed recently in both rapeseed species (*Brassica napus* L. and *B. campestris* L.) are a result of pressure from the processing industry to provide low erucic acid content in the oil and low glucosinolate content in the meal. Therefore the major emphasis in research regarding rapeseed has been concerned with its 'seed quality package'.

Changing crop development to increase yield, using either genetic manipulation or husbandry requires information on the physiological processes that determine yield (Freyman *et al.*, 1973). The seed yield of any crop depends on the supply of organic and inorganic nutrients from the vegetative parts of the plant to the developing fruits (Flinn and Pate, 1970). In cereals, the ear and subtending leaf of the fruiting tiller make a major contribution of photosynthate to the developing grain (Thorne, 1965). Mobilization from senescing shoot tissues also contribute nitrogen and other essential elements (Kreideman, 1966). Sink capacity of the grain, photosynthetic capacity of the crop and pattern of assimilate distribution have also been identified as suitable criteria in breeding for higher yield (Bingham, 1972).

There is an abundance of information available on physiological processes in cereals. Information is also now accumulating for dicotyledonous seed crops. Since many of the dicotyledonous crops exhibit axillary and sequential flowering in contrast to the terminal and synchronous flowering of cereals, there is reason to suggest that they might also differ basically in the mode of nutrition of their fruits (Flinn and Pate, 1970).

Plant Growth Analysis

Phillipson, 1966

> "The biological capacity of the earth depends ultimately on the energy received from the sun; and man, to satisfy amongst other things his demand for food, depends on the use to which this energy is put by living organisms."

Methods exist for the quantitative analysis of this flow of energy at a fundamental stage: the growth of the whole autotrophic plant in relation to its environment (Hunt, 1978). The technique of quantifying the growth and development of whole plants by use of growth functions was developed by British plant physiologists and has become known by the informal title 'Plant Growth Analysis' (Wolf and Carson, 1973).

Growth involves changes in size, in form, and in number, all of which are strongly interlinked (Hunt, 1978). However, for the purposes of this thesis, the term growth denotes an increase in size, hence leaving out any qualitative concepts. When growth is considered as being primary productivity of a population, community or individual, it may be defined as the net daily gain in dry matter production (Blackman, 1968). On average, 85-90% of the dry matter of plants is carbonaceous material derived from photosynthesis (Milthorpe and Moorby, 1979).

Development refers to those changes in the form of the growing plant or plant part that may be regarded as a consequence of differential growth along the various axes or between different parts of the structure (Richards, 1969). A more all-encompassing definition denotes development as "ordered change or progress, often towards a higher, more ordered, or more complex state" (Bidwell, 1974). Development may take place without growth and vice versa, but the two are often combined in a single process.

The growth of a higher plant is intimately associated with increases in cell number and cell size (Richards, 1969). Ontogenetic trends in plant growth may be considered in two phases. First, when cell division predominates and is not constrained by resource availability, growth is exponential. As growth is progressively restricted by depletion of resources, loss of meristematic activity and the processes of maturation and differentiation, the growth increments per unit time decline to zero. In a population, interplant competition may become increasingly important in determining per plant resource availability as ontogeny proceeds.

Two assessments are required to carry out a simple growth analysis (Radford, 1967):

1. a measure of the plant material present (W) and,
2. a measure of the magnitude of photoassimilatory system of that plant material (A).

The Growth Rate (GR) of an individual plant, or Crop Growth Rate (CGR) of a unit area of canopy cover, at any instant in time (t) is defined as 'the increase of plant material per unit of time' (Radford, 1967):

$$\text{i.e., GR or CGR} = \frac{dW}{dt}. \qquad (2.1)$$

It follows from 2.1 that Mean CGR ($\overline{CGR}$) over a time period from t_1 to t_2 is given by (Radford, 1967);

$$\overline{CGR} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{dW}{dt}\, dt \qquad (2.2)$$

therefore

$$\overline{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \qquad (2.3)$$

where W_1 and W_2 are the values of W at times t_1 and t_2 respectively. This implies that the average slope along the relevant portion of growth curve is simply the slope of the straight line joining its two delimiting points (Richards, 1969). The only assumption necessary to carry out the integration in 2.2, is that the total plant dry weight varies without discontinuity throughout the period t_1 to t_2. This condition is bound to be fulfilled in all plants whatever their stage of development, unless some part of the plant is physically removed, or cut from it during that period.

Absolute growth rate or crop growth rate varies with initial plant size and time duration of growth before measurement. For example, sunflower plants have a higher absolute growth rate than chickweed at the same stage of development, primarily due to initial size differences, rather than to any differences in assimilation efficiency (Causton, 1977). For comparative purposes, the rate of dry matter production is adjusted to compensate for absolute differences in plant size. The absolute growth rate at any time, dW/dt, divided by W at the start of the growth interval, is known as the Relative Growth Rate (RGR) and is defined as 'the increase in plant material per unit of material per unit of time' (Radford, 1967);

$$\text{i.e., } \overline{RGR} = \frac{1}{W} \times \frac{dW}{dt} \qquad (2.4)$$

Relative growth rate is a measure of the efficiency of plant material in producing new material (Blackman, 1919). Equation 2.4 is equivalent to (Radford, 1967);

$$RGR = \frac{d\,(\log(e)\ W)}{dt} \qquad (2.5)$$

therefore, Mean RGR ($\overline{RGR}$), requiring the integration of equation 2.5;

$$\text{i.e., } \overline{RGR} = \frac{1}{t_2 - t_1} \left[\log(e)\ W\right]_{W_1}^{W_2} \qquad (2.6)$$

or

$$\overline{RGR} = \frac{\log(e)\ W_2 - \log(e)\ W_1}{t_2 - t_1} \qquad (2.7)$$

Equation 2.5 tells us that instantaneous relative growth rate is the slope of the plot of the natural logarithms of W against t (Hunt, 1978). Equation 2.7 will always give the correct $\overline{RGR}$ between two harvests regardless of the way the plants are growing during the interval (Radford, 1967). If the harvest intervals are long, $\overline{RGR}$ follows RGR only crudely, but as the intervals become shorter so the correspondence between these two estimates becomes progressively closer.

A useful measure of the photosynthetic efficiency of plants is Unit Leaf Rate (ULR) defined by Briggs *et al.* (1920) as 'the rate of increase of dry weight per unit leaf area';

$$\text{i.e., ULR} = \frac{1}{A} \times \frac{dW}{dt} \tag{2.8}$$

Unit leaf rate has also been called 'net assimilation rate', however the former term is most appropriate (Evans, 1972; Hunt, 1978).

Mean ULR ($\overline{ULR}$) given by equation 2.9 (Radford, 1967);

$$\overline{ULR} = \frac{W_2 - W_1}{A_2 - A_1} \times \frac{(\log(e)\ A_2 - \log(e)\ A_1)}{t_2 - t_1} \tag{2.9}$$

is appropriate for the $\overline{ULR}$ between two harvests regardless of how the whole plant and leaf area are growing with respect to time, but subject to the constraint that there is a linear relationship between whole plant dry weight and leaf area.

Leaf Area Ratio (LAR) is an estimate of the leafiness of the plant and is defined as 'the ratio of total leaf area to whole plant dry weight' (Briggs *et al.*, 1920). It is equivalent to (Radford, 1967);

$$\overline{LAR} = A/W \qquad (2.10)$$

and over a harvest interval its mean value, $\overline{LAR}$, is simply given by;

$$\overline{LAR} = \frac{(A_1/W_1) + (A_2/W_2)}{2} \qquad (2.11)$$

if one assumes that LAR is linearly related to time.

At any instant in time the following relationship holds (Radford, 1967);

$$\frac{1}{W}\frac{dW}{dt} = \frac{1}{A}\frac{dW}{dt} \times \frac{A}{W} \qquad (2.12)$$

or

$$RGR = ULR \times LAR$$

Simply expressed, the growth rate of the plant depends simultaneously upon the efficiency of its leaves as producers of new material and upon the leafiness of the plant itself. Except in very special circumstances,

$$\overline{RGR} \neq \overline{ULR} \times \overline{LAR} \qquad (2.13)$$

since equation 2.12 holds only crudely for mean values of the three quantities. Although it is assumed that leaves are the sole assimilatory organs, pods and stem parts are also sources of photosynthates during the seed production period (Allen *et al.*, 1971; Brar and Thies, 1977).

The crop-oriented concept of leafiness in relation to land area was termed 'Leaf Area Index' (LAI) (Watson, 1947). LAI is defined as 'the total leaf area of the plant material per unit area of ground' (Radford, 1967);

$$\text{i.e. } LAI = A/P \quad (2.14)$$

where P represents the land area from which A was measured. The overall yield of the crop is controlled both by the efficiency of the leaves of the crop as producers of new material and by the leafiness of the crop itself (Hunt, 1978).

As with RGR, instantaneously

$$CGR = ULR \times LAI, \quad (2.15)$$

which represents the central relationship in the study of population and community growth (Hunt, 1978). However, in most cases

$$\overline{CGR} \neq \overline{ULR} \times \overline{LAI} \quad (2.16)$$

When LAI is plotted against time, the resulting curve allows an examination of the time-course of leaf area, but also an estimate of the 'whole opportunity for assimilation' (Watson, 1947). The integral of the area lying beneath the $\overline{LAI}$ vs. time curve was termed 'Leaf Area Duration' (LAD), since it takes account both of the magnitude of leaf area and its persistance in time (Radford, 1967);

$$\text{i.e., } LAD = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} A\, dt \quad (2.17)$$

In experiments involving most forms of plant growth analysis, the experimenter has to decide which of two approaches to take (Hunt, 1978):

(i) the 'classical approach', in which the course of events is followed through a series of relatively infrequent, large samples,

(ii) the 'functional approach' in which the samples are smaller but more frequent.

The two approaches are not mutually exclusive if time and space are no object. The calculation of various growth parameters as mean values over the period of time intervening between two harvests has been the traditional approach for most of the sixty years that have elapsed since the early origins of the subject. A major deficiency in this approach is that it does not pay due regard to time-dependent ontogenetic changes in growth parameters (Nicholls and Calder, 1973). In addition, inter-harvest variability tends to yield markedly irregular trends in relative growth rate and unit leaf rate when calculated by the 'classical' methods (Venus and Causton, 1979).

The basic relationships of A with t and W with t should be our primary consideration, with a view to discovering the form of these growth curves (Radford, 1967). The main advantage in using fitted curves is that inter-harvest variability, which tends to result in irregular time trends in derived growth functions, are smoothed out (Venus and Causton, 1979). A series of estimates of the growth attribute may be calculated as many times as desired and these estimates are less disturbed by biological variability.

Inevitably, since the main aim is a smoothing device, the polynomial family of functions has been selected for the purpose of growth analysis (Causton, 1977). The great flexibility of the curves themselves and the simple mathematical and statistical properties enable them to be fitted to data by the exact and relatively straight-forward methods of linear regression. When alternative functions to polynomials are considered, particularly any that are based on a simple but realistic biological model, the immediate difficulty is that they are statistically non-linear (Venus and Causton, 1979). Since polynomials are useful for smoothing and forecasting purposes, the only requirement of the fitted curve is that it should closely follow the measured values of the growth attribute being measured (i.e., the curve is merely being used as a smoothing device to provide a clearer picture of the trend involved when presenting the results graphically). The particular mathematical form of the function used is now regarded as of no special physiolocal significance, but accuracy in the fit becomes the primary aim.

Hunt, 1979

> "The rationale behind the use of the fitted function is then simple; if attempts to assess the reality of growth result in a time series of observations scattered randomly about that reality, then a suitable mathematical function fitted to those observations may be expected to regain much of the clarity with which reality is perceived by the experimenter. In a sense, the course of the flow of understanding is reversed and the fitted function reflects back - not perfectly of course, but at least in the right direction - towards that reality of which the observational data are an imperfect

> estimate. Paradoxically, the fitted functioncan be of more value to the experimenter than the data from which it was derived."

Growth Parameters

Trends in crop dry weight (CDW), $\overline{\text{CGR}}$, $\overline{\text{RGR}}$, $\overline{\text{ULR}}$ and LAI can be used to interpret growth and yield differences among species, forma, and genotypes of *Brassica*. In particular, the growth and development of *B. napus* L. (S.T.) can be considered physiologically in four more or less distinct phases according to the pattern of dry weight production (Allen *et al.*, 1971):

I. vegetative or pre-anthesis phase in which $\overline{\text{CGR}}$ and LAI increase linearly and attain a peak.

II. an approximate 2-3 week period immediately following anthesis in which there is a marked reduction in $\overline{\text{CGR}}$ coinciding with leaf senescence and declining LAI.

III. a further 2 week period in which $\overline{\text{CGR}}$ increases to a much higher level than that attained in phase I and characterized by a marked increase in the size and weight of pods.

IV. a final period ending at full maturity during which total plant weight decreases.

CDW of the highest-yielding cultivar of *B. napus* L. was greater than lower-yielding cultivars during two periods of growth and development; during the flowering period when the LAI's of the highest-yielding cultivar were superior, and during pod growth when the highest-yielding cultivar produced a greater weight of pods (Allen and Morgan, 1975). The total dry weight of the plant at flowering to some degree reflects the potential metabolic input of the plant (Thurling, 1974). In *B. napus* L. a sharp reduction in the total dry weight of the plant at anthesis was associated with a decrease in the number of pods per plant, without any significant change in the seed weight per pod. Although there was a slight rise in the total dry weight of *B. campestris* L. (S.T.) over the same interval, there was still a substantial reduction in the number of pods per plant, which, however, was associated with a proportionately greater increase in the seed weight per pod (Thurling, 1974).

$\overline{\text{CGR}}$ of field grown *B. napus* L. (S.T.) increased during vegetative growth and reached its highest levels prior to flowering (Allen *et al.*, 1971; Allen and Morgan, 1972, 1975; Scott *et al.*, 1973a; Major 1977; Clarke and Simpson, 1978a). The period of time over which $\overline{\text{CGR}}$ will decrease during flowering and the extent of its decrease depend upon when flowering occurred with respect to maximum LAI. Although $\overline{\text{CGR}}$ decreases significantly during flowering, it increases rapidly during pod development, reaching maximal values coinciding with large increases in the size and weight of pods (Allen *et al.*, 1971; Allen and Morgan, 1975; Clarke and Simpson, 1978a). In particualr, $\overline{\text{CGR}}$ of the highest yielding cultivar amongst four cultivars examined of *B. napus* L. (S.T.), was significantly greater than that of the low yielding cultivars during two distinct phases of development, the flowering and pod filling periods (Allen and Morgan, 1975). However, in other studies (Scott *et al.*, 1973a; Major, 1977), maximal values of $\overline{\text{CGR}}$ during intensive dry matter accumulation in the seed of *B. napus* L. (S.T.) was not evident. Infrequent sampling (i.e., weekly, fortnightly) which is unable to detect short-term peaks in $\overline{\text{CGR}}$ may have been the cause for these inconsistencies.

No increase in $\overline{\text{CGR}}$ was observed for *B. campestris* L. (S.T.) during pod development in field experiments conducted in western Canada (Major, 1977). $\overline{\text{CGR}}$ was significantly greater in *B. napus* L. than *B. campestris* L. at all sampling dates except the first one. The peak in $\overline{\text{CGR}}$ during pod development of *B. napus* L. (winter-type (W.T.)) was much more pronounced than that of *B. napus* L. (S.T.) (Scott *et al.*, 1973a). The coincidence of pod development in *B. napus* L. (W. T.) with short term peaks in solar radiation may have resulted in the higher peak in $\overline{\text{CGR}}$ during pod development.

The $\overline{\text{RGR}}$ of *B. napus* L. (S.T.) was significantly greater than that of *B. campestris* L. (S.T.) (Thurling, 1974). However, a major shortcoming of Thurling's study was that $\overline{\text{RGR}}$'s between species were compared on the basis of days, not developmental phases.

The $\overline{\text{ULR}}$ of *B. napus* L. (S.T.) declined from a high during early vegetative growth to a low during flowering, but increased again during ripening (Clarke and Simpson, 1978a). The upswing in $\overline{\text{ULR}}$ during the ripening period, suggests increased photosynthetic efficiency (Clarke and Simpson, 1978a). A similar occurrence is present in other studies of *B. napus* L. (S.T.) (Allen and Morgan, 1972, 1975). However, this phenomenon is probably due to an underestimate of the photoassimilatory area of the plant (Milbourn and Hardwick, 1968). In *B. napus* L. (W. T.) maximum photosynthetic rate of the plant occurs before the attainment of maximum pod area, after which the photosynthetic rate of all plant parts declined (Inanga and Kumara, 1974). The importance of pods and stems in producing carbon assimilates (Brar and Theis, 1977; Major and Charnetski, 1976) results in a significant underestimation.

The largest genotypic differences in LAI occurred during the flowering period of *B. napus* L. (S.T.) varieties in which the highest yielding variety had the greatest LAI (Allen and Morgan, 1975). Although genotypes differed in rates of leaf emergence, the genotype with the fewest number of leaves per plant had the highest LAI. However, during the flowering period the genotype with the highest LAI had the greatest number of leaves per plant. However, in *B. napus* L. (W. T.), LAI maintained relatively high values throughout pod development. This is contrasted with reports for *B. napus* L. (S.T.) where complete senescence coincided with pod onset (Allen *et al.*, 1971). Maximum LAI was reached approximately three weeks after first flower in *B. napus* L. (W. T.) and one week before first flower in *B. napus* L.

(S.T.) (Scott *et al.*, 1973a). LAI of *B. napus* L. (S.T.) increased to a maximum during pre-anthesis and declined thereafter, coinciding with the period of flower opening (Allen *et al.*, 1971). LAI's reached insignificantly low values with the onset of pod formation and senesced to zero as intensive pod growth began.

The leaves of *B. campestris* L. (S.T.) senesced entirely one week before maximum seed dry weight was reached, whereas some of the leaves of *B. napus* L. (S.T.) remained green even after seed dry weight had reached its maximum (Major, 1977). This, combined with significantly higher maximum LAI in *B. napus* L., results in significantly larger leaf area durations being reported for *B. napus* L. than *B. campestris* L. (Thurling, 1974; Major, 1977). LAD after anthesis was significantly larger in the higher-yielding *B. napus* L. (W. T.) than *B. napus* L. (S.T.) (Scott *et al.*, 1973a).

Developmental Morphology Parameters

Another approach to growth pattern analysis is the quantitative description of major observable growth stages, growth periods and rates of development (Campbell and Kondra, 1977). Growth pattern characteristics were analyzed in relationship to yield and yield components to determine what traits were associated with high yield of *B. napus* L. (S.T.) under low heat-unit conditions.

Time to first flower was a major factor in determining the time to maturity (Campbell *et al.*, 1978). The cultivar

Target (*B. napus* L. (S.T.)) was significantly later than the cultivar Oro (*B. napus* L.) for all growth stages during the rosette period. Onset of elongation occurred on the same day for both cultivars, while first flower and all growth stages subsequent to first flower occurred significantly earlier in Target than in the late maturing Oro (Campbell and Kondra, 1977). The correlation of first flower with maturity was significant for all three cultivars of *B. napus* L. (Campbell *et al.*, 1978), indicating that selection for early first flower could result in early maturity. In *B. napus* L., the earlier flowering and maturing cultivar had a significantly lower rate of leaf development and flowering rate of racemes than the later maturing cultivar (Campbell and Kondra, 1977).

In Great Britain, the period of flowering production spanned approximately three weeks in both the high and low yielding cultivars of *B. napus* L. (Allen and Morgan, 1975). In western Canada, the flowering period of the latest maturing, lowest yielding cultivar Oro (*B. napus* L.) spanned 21.3 days and decreased with delayed seeding, while the flowering period for the earliest maturing, highest yielding genotype, 74-1382, spanned 19.4 days and increased with delayed seeding (Degenhardt and Kondra, 1981b).

Substantial variation exists among cultivars of *B. napus* L. (S.T.) with respect to the lengths of the two major pre-anthesis developmental phases: vegetative (seeding date to onset of elongation) and stem elongation (onset of elongation to anthesis) (Thurling and Vijendra Das, 1977). Under controlled environments, the duration of the vegetative phase of *B. napus* L. is strongly influenced by vernalization, photoperiod and growing temperature (Thurling and Vijendra Das, 1977; Major, 1980). The duration of the stem elongation phase is affected primarily by photoperiod and growing temperature. Decreases in temperature were more important than decreases in photoperiod in significantly delaying the appearance of the first open flower. The direct effect of temperature on rate of leaf node formation of *B. napus* L. was more important than the inductive response (no. of leaf nodes at initiation) in determining flowering time in all Canadian cultivars.

Photosynthesis and Assimilate Distribution

The attainment of characteristic form and function in a crop plant depends upon a chain of interrelated events, which are sequential in time, and subject to the modifying influences of nongenetic forces (Adams, 1967). The "law of limiting factors" supplies much of the rationale behind contemporary discussion of whether supply of assimilates (i.e., source) or the capacity for their storage (i.e., sink) limits crop yields. In cereals, grain filling is largely dependent on photosynthesis and environmental conditions after flowering, but the capacity for storage is determined by conditions before flowering. In plants with sequential axillary flowering, the period when storage capacity is determined overlaps the period of storage itself, and mutual adjustment of the two components may be more readily achieved.

The time of first flower is pivotal to determination of maximal LAI at anthesis and LAD from anthesis. By definition, first flower determines the duration of the vegetative period and also largely determines subsequent reproductive periods (Campbell and Kondra, 1977, 1978), which depend on the assimilate supply for realization of its reproductive potential. The relative importance of the vegetative period and reproductive period in determining final economic yield is not fixed, but varies with the genotype and agronomic treatments imposed, all interacting and superimposed upon prevailing environmental conditions.

The role of early plant growth in *B. napus* L. (S.T.) should be interpreted in terms of the accumulation of dry matter in the seeds (Brar and Theis, 1977). Fully expanded leaves in vegetative plants contribute assimilates mainly to the younger developing leaves and to the root system. During active development of the terminal and axillary inflorescences of *B. napus* L., the gain in weight from photosynthesis by an area of leaves which was senescing and declining in size was nearly balanced by the lossin weight from respiration (Allen et. al., 1971), the rate of which probably was increasing with active development of flowers (Gaastra, 1963). This indicates increased demand for assimilates due to increased respiration rates in reproductive structures beginning with flower bud development. Respiration is not an independent process, but is closely related with the physiological activity of different plant tissues. Little information exists concerning respiration rates of various plant organs throughout the ontogeny of crop growth.

The physiological basis for differences in the yield of seed for *B. napus* L. (S.T.) in different varieties can be linked with differences in number of pods per plant, which in turn, are principally determined by the leaf area at anthesis and LAD from anthesis (Allen and Morgan, 1975). In plants beginning to flower, fully developed leaves, which were located on the middle to upper portion of the stem, promoted mainly the structural development of the part of the stem bearing the flower (Brar and Theis, 1977). Of the proportion of labelled photosynthates exported by the fifth leaf, approximately 70% was utilized in structural development of the rapidly elongating stem and developing buds. A drop in $\overline{\text{ULR}}$ of *B. napus* L. (S.T.) during the flowering period, probably was due to the lower photosynthetic efficiency of ageing and senescing leaves and the increased rate of respiration of the inflorescence (Allen and Morgan, 1972). High yielding genotypes of *B. napus* L. developed more pods because they were able to maintain a better rate of supply of carbon assimilates to the pods when their number and the number of seeds they contain were being determined (Allen and Morgan, 1975). The low yielding variety had more unproductive, lower positioned inflorescences, which would have drawn on the supply from the leaves which subtended them. These assimilates otherwise would have gone to the earlier-developing pods carried on the higher positioned inflorescences. Axillary inflorescences depend for their supply of carbon assimilates on those they manufacture themselves and on those which come from the leaves which subtend them and leaves inserted vertically below them (Tayo, 1974). The overwhelming evidence supports the need for the maintenance of a large and photosynthetically efficient leaf area at anthesis and over the period when the number of seeds per pod is being determined (Allen and Morgan, 1972). Also, minimizing the number of non-productive inflorescences leads to an increase in the supply of carbon assimilates to productive pods (Allen and Morgan, 1975). In glasshouse experiments with *B. napus* L. (S.T.), the first flower to open was the most basal one on all inflorescences and flowering proceeded acropetally (Tayo and Morgan, 1975). The terminal raceme was first to flower, followed later by axillary inflorescences on the first, second, third, fourth and fifth node respectively. The period of flower opening over the whole plant spanned 26 days, which also represented the flowering period of the terminal raceme. While flower production ceased about the same time on all inflorescences, the last axillary inflorescence to flower bore open flowers for only 14 days. Compensation for inadequate pollination in *B.*

campestris L. (S.T.) resulted in a longer period of flowering, increased flower production, and heavier seeds (Williams, 1978).

Abortion, the failure of pods to elongate, increase in girth and become seed bearing, was substantial for both *B. napus* L. (S.T.) and *B. campestris* L. (S.T.) (McGregor, 1981). Abortion occurred predominantly towards the end of the flowering period or after, and was most prevalent on the later-developing inflorescences. The likelihood of a flower setting decreased progressively from the lowest to the uppermost flower, and pods low on the terminal raceme contained more seeds than those at the top (Williams, 1978). The number of flowers produced far exceeded the number of pods formed (Tayo and Morgan, 1975). While most flowers were formed on terminal raceme and basal and middle regions of the axillary inflorescences arising from the uppermost 3 nodes, only 45% of flowers which did open developed into pods which were retained. Most plants of *B. napus* L. carried a terminal raceme with nine axillary racemes of which only the upper five bore both open flowers and pods; flower buds on other inflorescences aborted as development proceeded. Secondary inflorescences developed on some axillary inflorescences, but few bore flowers and none retained pods. Seventy-five per cent of the pods retained to maturity were formed from flowers which opened within a period of eleven days after anthesis. This finding was supported by Allen and Morgan (1975), who found that approximately 75% of the total number of pods were on the terminal raceme. The smallest and therefore later formed pods were lost in the later stages of development (Allen and Morgan, 1975).

In *B. napus* L. (S.T.) 20% or 40% bud removal at flowering did not diminish seed yields per plant or number of pods per plant (Williams and Free, 1979). The ability of cultivars of *B. napus* L. to reduce abscission of flowers and pods has been suggested as a major yield-determining factor. Both the number of pods and number of flowers were reduced with shading of leaves for one week from first flower and one week thereafter, while shading from two weeks after first flower reduced only the number of pods (Tayo and Morgan, 1979). These results suggest that the number of pods which develop and are retained can be regulated by the supply of carbon assimilates to the inflorescence throughout the period from first flower until three weeks thereafter. Similarily, defoliation of *B. napus* L. at first flower significantly reduced seed yield per plant, number of pods per plant, and number of branches per plant (Clarke, 1978). Defoliation at the end of flowering had no significant effect on seed yield or yield components. Shading of leaves one or two weeks after anthesis showed compensation for reduced pod numbers by an increase in seeds per pod in the basal and middle regions (Tayo and Morgan, 1979). Stresses in the supply of carbon assimilates around the time of anthesis are particularly harmful, since, in addition to reducing the number of pods which develop, they appear to restrict the capacity for compensatory growth in the pods that remain when the supply returns to normal. In *B. napus* L., the limited growth of pods following shading for one week from anthesis may have been due to fewer ovules capable of fertilization and fewer cells available for expansion as a consequence of the reduction in carbohydrate supply during differentiation of the ovary (Tayo and Morgan, 1979).

Defoliation of *B. campestris* L. (S.T.) during late anthesis resulted in a significant yield reduction of approximately 50% (Freyman *et al.*, 1973) of the control's yield. Defoliation shortly after flowering in *B. napus* L. (S.T.) reduced yields 50%; removing half the leaves or shading all of them reduced yields to 70% of the control, and shading half the leaves reduced yields to 90% of the control (Holland, 1971).

The more severe reductions in the number of pods and seed yields with the leaf removal treatment can be correlated with shortages of carbon assimilates which would have followed leaf removal (Tayo and Morgan, 1979). The removal of leaves two weeks before anthesis was least stressful because of the regeneration of leaf area through the expansion of bracts and the development of axillary shoots. Where the number of pods had been reduced the most (i.e. shading for two weeks prior to anthesis), the mean pod weight was highest, and where pod reduction was least (shading for two weeks, two weeks after anthesis), the mean pod weight was the smallest (Tayo and Morgan, 1979). Differences in mean pod weight were associated more with differenced in numbers of seeds per pod than with any other character. These results point to the importance of the supply of carbon assimilates from before until well after anthesis in regulating the numbers of flowers, pods, and seeds, which develop as well as the weights attained by the individual pods and their constituents (Tayo and Morgan, 1979).

Irrespective of the stages of development over which shading took place in *B. napus* L. (S.T.) the reductions in number of pods occurred in the middle and apical regions of the inflorescence (Tayo and Morgan, 1979). This indicates that the basal and first developed pods have a competitive advantage over the younger, more apically positioned ones when the supply of assimilates is decreased. Both inter- and intra-inflorescence competition is probably of major importance in determining the pattern of flower and pod development within and between inflorescences (Tayo and Morgan, 1975). Removing fifteen of the most basal flowers or pods led to an increase in the supply of assimilates to the more apically positioned flowers and pods. The basal and older pods responded more in terms of heavier pod walls and seeds, while the more apically positioned and younger pods developed more seeds per pod as well as heavier pod walls (Tayo and Morgan, 1979).

High correlations between pod surface area and seed yield have been reported for *B. campestris* L. (S.T.) (Maiti *et al.*, 1970), while similar relationships have not been reported in *B. napus* L. (Clarke and Simpson, 1978b). This may be due to a relatively greater contribution to seed yield by leaves than pods in *B. napus* L. Leaves exert an early effect on seed yield by influencing the development of sink capacity. The correlation between LAI and seed yield would be expected to be greater than between pod area and seed yield.

Compensation is inevitable when sequentially developing yield components share a common source of metabolites (Adams, 1967). No compensation between number of pods per plant and number of seeds per pod could be the result of seed number being influenced by assimilate production in the pods themselves, whereas pod number was influenced by assimilates supplied by leaves during the flowering period (Clarke and Simpson, 1978a). Compensation by seed size for low pod or seed number in *B. napus* L. cultivar Tower was found by Clarke and Simpson (1978b).

Seed weight increases of *B. napus* L. (S.T.) were associated with a decrease in the weight of the pod walls, suggesting a movement of assimilates from the pod wall to the seeds (Allen and Morgan, 1975). Since increased seed number per pod under irrigation may have resulted from increased assimilate supply and greater pod surface area, Clarke and Simpson (1978b) suggested that the number of seeds per pod is determined primarily by the ability of the individual pod to supply assimilates at the time when final seed number is being determined. A technique of radiography employing the use of X-radiation to compare inter- and intra-inflorescence pod development has indicated a close correlation between pod size and number of seeds per pod (Pechan *et al.*, 1980). The terminal inflorescence carries more pods with large numbers of seeds. Apically positioned pods are smaller and carry fewer seeds (Williams, 1978). These findings are in accordance with the observation that when the distance from source to sink increases, the amount of assimilates reaching the sink decreases (Biddulph, 1969).

Defoliation of *B. campestris* L. (S.T.) at late anthesis resulted in significantly reduced yields, in which defoliated plants yielded approximately 65% of the intact plants (Freyman *et al.*, 1973). Leaves, stems, pods and beaks all possess stomata and have the potential to assimilate CO_2 (Major, 1975). In studies utilizing $^{14}CO_2$ to assess the role of leaves in the formation of seed of both annual rapeseed species, photosynthates were translocated from leaves to the seed (Freyman *et al.*, 1973). The uppermost true leaf of *B. napus* L. (S.T.) translocates nearly 75% of its assimilates to the growing fruits (Brar and Theis, 1977).

Roots, pods, beaks, seeds and apices were sinks for assimilates in both rapeseed species (S.T.) while both stems and leaves were found to export ^{14}C-labelled assimilates (Major and Charnetski, 1976). Photosynthates produced in leaves of both rapeseed species (S.T.) were translocated selectively to the pods in which seeds were filling, and there appeared to be no translocation to barren pods (Freyman *et al.*, 1973). Lower leaves of *B. napus* L. (S.T.) exported photosynthates to the root, whereas upper stems and leaves exported photosynthates to seeds and pods (Major *et al.*, 1978). Seeds were a strong sink for photosynthate translocation from leaves pods and stems. Although pods were capable of assimilating $^{14}CO_2$, they were also sinks for photosynthate exported from stems and leaves.

At the stage of most intensive accumulation of dry matter in the seeds of *B. napus* L. (S.T.), the silique walls and stem parts bearing siliques showed a relatively high photosynthetic activity compared to that of the leaves (28% and 41% respectively; leaves = 100%) (Brar and Theis, 1977). Correspondingly high quantities of assimilated ^{14}C were delivered by these organs to the growing seeds; leaves 37%, silique walls 32%, and stems 31%. In this study and others involving either *B. napus* L. or *B. campestris* L. (S.T.), no distinction is made between leaves which are attached to the main stem and those attached to the stem part bearing siliques.

A study of total dry matter production in relation to leaf area suggests that the source of assimilates for flower and early pod development is different from that for later pod growth (Allen and Morgan, 1975). Up to the time of emergence of green pods, flower and post-fertilization development depends primarily on assimilates supplied by the leaves and, to a lesser degree, stems. Seed weight appears to be determined late in the ripening phase (Norton and Harris, 1975), while pod number is determined immediately following flowering. Since reductions in pod number were compensated for by increased number of seeds per pod, seed number is primarily determined by assimilates available shortly after first flower. However, after the formation of pods, it seems probable that the green pods produce the assimilates for their own growth and that of the seeds which they contain and thus leaves become decreasingly important as sources of assimilate for their growth (Allen and Morgan, 1975; Allen *et al*., 1971).

The best avenue for yield improvement would be to improve the supply of metabolic inputs during the development of each yield component (Adams and Grafius, 1971). For *B. napus* L. (S.T.), this would mean increasing leaf area, or its duration, to supply assimilates during pod development, and also increasing pod area or photosynthetic rate to supply assimilates for seed growth (Clarke and Simpson, 1978b). Limitation of branching and increasing pod numbers on the main raceme could also be beneficial in terms of increased yield and earlier maturity (Clarke and Simpson, 1978b).

Yield Components and Interrelationships

Seed yield per unit area of rapeseed is a function of number of pods per unit area, number of seeds per pod, and weight per seed. In examining the effects of plant density and irrigation on yield, 1000 seed weight and plant density were the most important components of yield (Clarke and Simpson, 1978b). The number of pods per unit area increased with increasing plant density while number of pods per plant declined. This led to a negative correlation between number of pods per plant and seed yield, which was in contrast to Thurling's (1974) finding of a positive correlation between seed yield and number of pods per plant in *B. napus* L. (S.T.). This would be expected at a fixed density, since number of pods per plant and number of pods per unit area would be directly related (Clarke and Simpson, 1978b). According to Degenhardt and Kondra (1981b), number of plants or number of racemes per plant are not major factors of seed yield per unit area.

Observations of single plants of three genotypes of *B. napus* L. (S.T.) grown in the field in solid stands, indicated that the major contributor to seed yield per plant was vegetative yield (Campbell *et al*., 1978). Further field studies with five genotypes of *B. napus* L. indicated that only harvest index had a consistently high correlation with seed yield per unit area. Therefore, harvest index could be a promising evaluation criterion for selecting genotypes in a *B. napus* L. breeding program for seed yield and early maturity (Degenhardt and Kondra, 1981b). Similarily, harvest index was the single most important character influencing seed yield per unit area in three cultivars of *B. napus* L. (S.T.) measured under field conditions. Variation in harvest index was independent of total yield of the plant (Thurling, 1974).

Seed yield per unit area of *B. napus* L. (S.T.) was determined primarily by the number of pods per plant and the number of seeds per pod, which in turn paralleled LAI in field experiments examining the effects of nitrogen (Allen and Morgan, 1972, 1975; Scott *et al*., 1973b) and genotype (Allen and Morgan, 1975). Under western Australian conditions, seed yields are primarily influenced by the number of pods per plant (Thurling, 1978).

In four cultivars of *B. campestras* L. (S.T.) grown in Kuwait as spaced single plants, seed yield per plant was positively and linearly associated with pod length, number of pods per plant, number of seeds per pod and seed weight per pod; all four component characters were interelated with plant height (Ahmed, 1980). On the average, 30% of the variability in seed yield per plant in *B. campestris* L. was due to its association with these four component characters. In *B. napus* L. (S.T.), increases in pod dry weight were largely responsible for increases in total plant dry weight during pod development (Allen *et al*., 1971), but average pod weight and average seed weight were not associated with seed yield per unit area (Allen and Morgan, 1972). Although the simple correlation coefficient between seed yield per plant and plant height was nonsignificant in *B. campestris* L., plant height exhibited a significant effect on seed yield per plant independent of other plant characters examined (Ahmed, 1980). Tall plants usually had more branches and more pods per plant than did short plants. Contrary to this, early-maturing, higher-yielding genotypes of *B. napus* L. which were shorter, had higher harvest indices, and lower vegetative yield than the taller, late-maturing genotypes, indicating that the selection of shorter plants within breeding material would be most desirable (Degenhardt and Kondra, 1981a).

Seed yield per unit area was associated primarily with total plant dry weight at final harvest, which in turn was most closely correlated with the duration of the vegetative period in field experiments examining the effects of seeding rate and date on Canadian spring cultivars of *B. napus* L. grown as winter crops in Western Australia (Thurling, 1974). Similar findings in other studies were observed within an individual genotype of *B. napus* L. However, for any given seeding date the genotype with the shortest vegetative period had the highest seed yield (Degenhardt and Kondra, 1981b). In the same way, within one genotype of *B. napus* L., number of racemes per unit area was not a major factor in determination of seed yield per unit area.

The total dry weight of the plant at final harvest and first flower of *B. napus* L. (S.T.) were both significantly correlated with the three leaf/size parameters; maximum LAI, LAD after anthesis, and leaf-weight ratio at anthesis (Thurling, 1974). Maximum LAI, LWR at anthesis, harvest index and pod production period all made significant contributions to seed yield per unit area of *B. napus* L. (Thurling, 1974; Scott *et al*., 1973a). Peak $\overline{\text{CGR}}$ during pod development, pod growth rate, pod dry weight, and total plant dry weight at anthesis paralleled seed yield per unit area (Allen *et al*., 1971; Allen and Morgan, 1972; Scott *et al*., 1973b). $\overline{\text{CGR}}$ paralleled LAI from germination to pod onset (Allen *et al*., 1971). A close linear relationship between LAD and maximum LAI was observed in *B. napus* L. (Scott *et al* ., 1973b).

Total plant dry weight and flower number at the time of floral initiation are significantly correlated to final yield (Fabry, 1979). Below a specific threshold, it is the production potential which is limited and is correlated with the dry matter present in the plant at the time of initiation of elongation. Above a specific threshold, there occurs the phenomenon of competition within the plant and between plants, which restrict the full yield potential of the plant (Fabry, 1979).

Since time to flowering and length of the seed formation periods did not give the same ranking of genotype as seed yield, there appeared to be no direct relationship between duration of flowering or seed formation and seed yield amongst genotypes of *B. napus* L. (Degenhardt and

Kondra, 1981b). This finding corresponds with those of Campbell *et al*. (1978) who found that seed filling period was not a significant factor in determining seed yield. The positive correlations of flowering rate of racemes with seed yield per plant indicates that a rapid rate of flowering is associated with high yield (Campbell *et al*., 1978). Earliness of the stages and periods, up to and including first flower on the third secondary raceme, increased duration of the flowering periods first flower to last flower and first flower to end flower also characterize plants with high yield levels (Campbell and Kondra, 1978). Growth rate, flowering rate, and rate of dry matter accumulation during seed formation under cool growing conditions may be major factors in yield determination (Campbell *et al*., 1978).

III. MATERIALS AND METHODS

Plant Material

The plant material included in this study was chosen to represent a range of maturity dates under central Alberta conditions.

Two cultivars of *B. napus* L. (S.T.) ('Oro' and 'Regent') and an experimental line from the University of Alberta breeding program ('74G-1382') were used in the field experiment carried out in 1979. The line 74G-1382 and cultivars Regent and Oro mature in approximately 105, 111 and 117 days, respectively.

Ten genotypes from two species (*B. napus* L. (S.T.) and *B. campestris* L. (S.T.)) grown in central Alberta were used in the field experiment carried out in 1980. The four experimental lines (74G-1382 or "1382", 75G-908 or "908", 75G-2180 or "2180" and 75G-1999B or "1999B") and four cultivars ('Altex', 'Tower', 'Regent' and 'Oro') representing *B. napus* L. (S.T.) mature in approximately 105, 107, 108, 108, 108, 110, 111, and 117 days, respectively. Two cultivars of *B. campestris* L. (S.T.) ('Candle' and 'Torch') mature in approximately 96 days.

Location

The two field experiments were conducted on a clay loam soil (solonetzic black soil type) at the University of Alberta, Edmonton Research Station. Temperature, precipitation and sunshine hours were recorded at a nearby meteorological station (Appendices 1, 2 and 3). Stored soil moisture was adequate for germination andgrowth in 1979. However, because of low soil moisture reserves in 1980, one sprinkle irrigation of 20mm was applied at the cotyledon stage.

Design of Experiments

All genotypes in both years were replicated four times in a randomized block design. In 1979, plots were 6 m long and 11.6 m wide with 52 rows per plot having 22.5 cm spacing between rows and 2.0 m spacing between blocks. In 1980, plots were 6 m long and 3.6 m wide with 16 rows per plot having 22.5 cm spacing between rows, and 2.0 m spacing between blocks.

Seeding

Fertilizer was broadcast and worked in three days prior to seeding, at the recommended rate of 100 kg/ha of 11-55=0 (11 kg/ha actual N, 55 kg/ha actual P) in 1979. In 1980, soil tests indicated no nutrient deficiences and therefore no fertilizer was applied.

Weeds were controlled by the incorporation of trifluralin herbicide at 0.5 kg/ha active ingredient four days prior to seeding in 1979. The test-site in 1980 was virtually free of weeds and no herbicides were applied. There were no weed problems in either year.

Seed was treated with carbofuran granules to control flea beetles in both years. There were no serious pest problems in either year.

The seed for each row was individually packaged to provide approximately 300 seeds per 6 m row in each plot for both years. In 1979 and 1980, plots were seeded on May 9 and May 8, respectively, In both years the seed was placed approximately 1 cm to 2 cm below the soil surface. Seeding rate, seeding date and depth of seeding were typical of cultural practices endorsed by central Alberta farmers. Plots were seeded with a Swift Current power seeder, four row cone-type press drill with double disc openers, which has wheels packing the soil before and after the seed is placed in the soil.

Sampling Procedure

Visual observations in the field of germination, plant density, leaf emergence and onset of stem elongation were taken at regular intervals until June 8 in 1979, and until May 20 in 1980. Subsequently, growth, development and yield were measured on samples cut at soil level from 0.5 m^2 areas in 1979, and from 0.25 m^2 areas in 1980. All sampling sites in both years were bordered by 0.5 m of discard area between rows and 0.25 m of discard area within rows.

In 1979, samples were taken at two-day intervals throughout the growing season, beginning June 9 and ending September 7, providing a total of 46 harvests. In 1980, samples were taken at two-day intervals from May 21 through to June 28, after which samples were taken at four-day intervals until September 5. A total of 38 harvests were taken in 1980. After harvesting, the plant material was brought to the field laboratory where the pertinent observations and measurements were rercorded. The samples were placed in forced air dryers at 60 degrees C for 48 hours after which their dry weights were measured.

Quantitative Analysis of Growth

The growth stage key (Table 1) was used in defining the major observable developmental events.

Observations, measurements, or calculations were taken on the following growth, development and yield characteristics. All variables are expressed in terms of land area basis.

1. Emergence of true leaves (code tl.1, tl.3, tl.5, and tl.7)

   The time between time of seeding (TOS) to emergence of first true leaf was rercorded when visual observations determined that 50% of the plants exhibited an exposed first true leaf a minimum of .5 cm in length. Determination of tl.3, tl.5 and tl.7 was similar.

2. Onset of stem elongation (code se.0)

   TOS to onset of stem elongation was recorded when visual observations determined that 50% of the plants had the first and second nodes growing apart.

Table [illegible] Growth Stage Key

Code	Stage	Description
tl.1	True Leaf 1	Emergence of the first true leaf
tl.3	True Leaf 3	Emergence of the third true leaf
tl.5	True Leaf 5	Emergence of the fifth true leaf
tl.7	True Leaf 7	Emergence of the seventh true leaf
se.0	Onset of stem elongation	Onset of internode elongation
abl.1	Axillary branch leaf 1	Emergence of the first leaf on an axillary inflorescence
stl.1	True Leaf 1 senesced	Senescence of first true leaf
f.1	First flower M	First flower on the main inflorescence
etl.0	End of true leaves	Senescence of the last true leaf
m.1	Maturity of first pod	Seeds in the lowest pod of the main raceme all dark colored

3. First axillary branch leaf (code abl.1)

TOS to emergence of first axillary branch leaf was recorded when visual observations determined that 50% of the plants exhibited an exposed first axillary branch leaf a minimum of .5 cm in length.

4. First true leaf senesced (code stl.1)

TOS to senesence of first ture leaf was recorded when visual observations determined that 50% of the plants exhibited the first true leaf to be 50% or greater senesced.

5. First flower (code f.1)

TOS to first flower was recorded when 50% of the plants had at least one open flower on the main raceme.

6. End of true leaves (code etl.0)

TOS to end of true leaves was recorded when 50% of the plants had no true leaves present. A living true leaf was defined as one having 50% or more of its area in a green state.

7. Maturity of first pod (code m.1)

TOS to maturity of the first pod was recorded when 50% of the plants had all mature brown colored seeds in the lowest pod of the main raceme.

8. Stem elongation period (se.0 to f.1)

The stem elongation period is the number of days from onset of stem elongation to first flower.

9. Seed formation period (f.1 to m.1)

The seed formation period is the number of days from first flower to maturity of first pod.

10. Leaf emergence rate

Leaf emergence rate was calculated for the period tl.1 to se.0, se.0 to f.1 and tl.1 to f.1. Simple linear regression was employed in determining leaf emergence rate. Leaves per plant were regressed on DAS (time) giving a leaf emergence rate expressed as "leaves per plant per day".

11. Crop dry weight

Crop dry weight is the total dry weight of plant material above soil level present in a $0.5m^2$ area in 1979, and obtained for a $.25m^2$ area in 1980.

12. Mean crop growth rate

$\overline{CGR}$ was calculated for the pre-anthesis period (TOS to f.1), seed formation period (f.1 to m.1) and over the complete life cycle (TOS to m.1) using equation 2.3. The pre-anthesis period is primarily vegetative and the post-anthesis period is primarily reproductive.

13. Mean relative growth rate

$\overline{RGR}$ was calculated on a land area basis for the pre-anthesis period (TOS to f.1), seed formation period (f.1 to m.1) and over the complete life cycle (TOS to m.1) using equation 2.7.

14. Leaf area index

LAI was calculated from the plant subsample leaf area and plant density. Measurements of leaf area were based on a random subsample of ten plants in 1979, and a random subsample of five plants in 1980. Subsampling was done at each sampling date from the time true leaves became apparent until m.1.

15. Mean unit leaf rate

$\overline{\text{ULR}}$ was calculated for the pre-anthesis period (TOS to f.1) using equation 2.9. The assumptions required for the use of equation 2.9 limits the calculation of $\overline{\text{ULR}}$ to the pre-anthesis period.

16. Mean leaf area ratio

$\overline{\text{LAR}}$ was calculated for the pre-anthesis period (TOS to f.1) using equation 2.11. The assumptions required for the use of equation 2.11 limits the calculation of $\overline{\text{LAR}}$ to the pre-anthesis period.

17. Leaf Area Duration

LAD was calculated from the integral of the function describing the relationship between LAI and DAS, between growth stages f.1 and m.1, using equation 2.17. This growth period was chosen since the assimilatory capacity of the leaves is of most interest during the seed formation period.

18. Axillary branch leaf area index (ABLAI)

ABLAI was calculated as the total axillary leaf area from the subsample and plant density. Measurements of axillary branch leaf area were made only in 1980 and were based on a random subsample of five plants. Subsampling was done at each sampling date from the time axillary leaves became apparent until m.1.

19. Axillary branch leaf area duration (ABLAD)

ABLAD was calculated from the integral of the function describing the relationship between ABLAI and DAS, between growth stages f.1 and m.1, using equation 2.17. Measurements of axillary branch leaf area were made only in 1980.

20. Plant density

Plant density was determined by counting the number of plants in $0.5m^2$ sample in 1979, and a $0.25m^2$ sample in 1980.

21. Seed yield

Seed yield was determined from the total yield sample from a $0.5m^2$ area in 1979, and a $0.25m^2$ area in 1980. An Almaco plot thresher, rub-bar type was used.

22. Harvest index

The harvest index was obtained by dividing the seed yield by the total yield.

23. Seed yield per main raceme

Seed yield per main raceme was determined from measuring the seed yield per main raceme from a ten plant subsample at m.1. Measurements on seed yield per main raceme were made only in 1979.

Analysis of Data

1. Analysis of variance (ANOVA)

The data from 1979 were analysed as a randomized block. The data from 1980 were analyzed as a nested design. Each year was treated as a separate experiment.

(i) ANOVA for 1979 field experiment

Source of variation	Degrees of freedom	F-value .05	F-value .01
replicate	3		
genotype	2	5.14	10.92
residual	6		
Total	11		

(ii) ANOVA for 1980 field experiment

Source of variation	Degrees of freedom	F-value .05	F-value .01
replicate	3		
species	1	10.13	34.12
genotype/species	8	2.35	3.35
replicate x species	3		
residual	24		
Total	39		

The valid error for "species" is "replicate by species", whereas for "genotype within species", the valid error is the residual.

Observed mean sample values were used in the ANOVA analysis for both years in determining all growth stage and growth period variables. In determining leaf emergence rate, simple linear regression was applied to observed mean sample values. The B values from the resulting linear polynomials were used in the ANOVA analysis.

The observed values for crop dry weight were transformed to natural logarithms to render their variability more homogeneous with time as evidenced by examining the residuals. Polynomials of varying degree were fitted to the transformed data by the least squares method. The polynomial of best fit is indicated in an analysis of variance table, which for each variate yields the ratio of the regression mean square for each particular order of fit to its residual mean square. A t-test was performed on the final coefficient of the polynomial to determine whether or not the addition of a further term giving a higher degree of polynomial was justified by the improvement in fit. The highest order polynomial that was justified was used, however, the same order of polynomial was used for all genotypes and all replicates. Through interpolation, predicted values were obtained for each genotype by replicate at specific developmental stages (i.e., f.1, 15DAF, m.1) for comparative purposes. The cubic polynomial (1979) and the quadratic polynomial (1980) were employed. Predicted values obtained from the above procedure were utilized in obtaining $\overline{CGR}$ and $\overline{RGR}$. Predicted mean values were used in the ANOVA analysis in comparing $\overline{RGR}$ and $\overline{CGR}$ values.

A similar procedure was used to obtain predicted values for LAI and ABLAI as that described for obtaining predicted values of crop dry weight. However, the observed values for leaf areas were not transformed to natural logarithms, since an analysis of residuals did not justify this transformation. Predicted mean values of LAI and ABLAI were used in the ANOVA analysis.

Predicted values obtained from the procedures outlined for crop dry weight and LAI were utilized in determining $\overline{ULR}$ and $\overline{LAR}$.

Observed values were used in the ANOVA analysis for both years in determining plant density, seed yield and seed yield per main raceme.

IV. RESULTS

In 1979, genotypes of *B. napus* L. (S.T.) differed significantly for all growth stages except tl.1 and se.0 (Table 2). Of the two growth periods analysed, there were significant differences for stem elongation period, but not seed formation period. Significant differences among genotypes for all growth parameters were indicated except for $\overline{\mathrm{ULR}}$ and $\overline{\mathrm{LAR}}$ (Table 2). Among genotypes of *B. napus* L. in 1979, all yield components except for seed yield differed significantly among genotypes (Table 2).

There were significant differences between species for all growth stages and growth periods (Table 2). Among the growth parameters, only $\overline{\mathrm{CGR}}$ (f.1 to m.1), $\overline{\mathrm{CGR}}$ (TOS to m.1) and ABLAI (15DAF) did not differ significantly (Table 2). Among the seed yield component characters, significant differences were indicated for seed yield, but not for harvest index or plant density.

In 1980, there were significant differences among genotypes of *B. napus* L. for all growth stages except tl.1 and all growth periods except seed formation period (Table 2). From tl.1 to f.1, the leaf emergence rate indicated significant differences among genotypes; however, from tl.1 to se.0 and se.0 to f.1 the differences among genotypes for leaf emergence rate were not significant (Table 2). Among the growth parameters; CDW (m.1), $\overline{\mathrm{CGR}}$ (f.1 to m.1), $\overline{\mathrm{CGR}}$ (TOS to m.1), LAI (15DAF) and LAD indicated no significant differences for seed yield components (Table 2).

Table 2. Summary of analyses of variance for all variables

	Within *Brassica napus* L. (1979)	Within *Brassica napus* L. (1980)	Within *Brassica campestris* L. (1980)	Between Species (1980)
tl.1	n.s.	n.s.	n.s.	*
tl.3	*	*	n.s.	*
tl.5	*	*	n.s.	*
tl.7	*	*	n.s.	*
se.0	n.s.	*	n.s.	*
abl.1	*	*	n.s.	*
stl.1	*	*	n.s.	*
f.1	*	*	n.s.	*
etl.0	*	*	n.s.	*
m.1	*	*	n.s.	*

Table 2. **Summary of analyses of variance for all variables (continued)**

	Within *Brassica napus* L. (1979)	Within *Brassica napus* L. (1980)	Within *Brassica campestris* L. (1980)	Between Species (1980)
SEP (se.0 to f.1)	*	*	n.s.	*
SFP (f.1 to m.1)	n.s.	n.s.	n.s.	*
LER (tl.1 to se.0)	*	n.s.	*	*
LER (se.0 to f.1)	*	n.s.	n.s.	*
LER (tl.1 to f.1)	*	*	n.s.	*
CDW (f.1)	*	*	n.s.	*
CDW (15DAF)	*	*	n.s.	*

Table 2. Summary of analyses of variance for all variables (continued)

	Within *Brassica napus* L. (1979)	Within *Brassica napus* L. (1980)	Within *Brassica campestris* L. (1980)	Between Species (1980)
CDW (m.1)	*	n.s.	n.s.	*
$\overline{\text{CGR}}$ (TOS to f.1)	*	*	n.s.	*
$\overline{\text{CGR}}$ (f.1 to m.1)	*	n.s.	n.s.	n.s.
$\overline{\text{CGR}}$ (TOS to m.1)	*	n.s.	n.s.	n.s.
$\overline{\text{RGR}}$ (TOS to f.1)	*	*	*	*
$\overline{\text{RGR}}$ (f.1 to m.1)	*	*	n.s.	*
$\overline{\text{RGR}}$ (TOS to m.1)	*	*	*	*

Table 2. Summary of analyses of variance for all variables (continued)

	Within *Brassica napus* L. (1979)	Within *Brassica napus* L. (1980)	Within *Brassica campestris* L. (1980)	Between Species (1980)
LAI (f.1)	*	*	n.s.	*
LAI (15DAF)	*	n.s.	n.s.	*
$\overline{\mathrm{ULR}}$ (TOS to f.1)	n.s.	*	n.s.	*
$\overline{\mathrm{LAR}}$ (TOS to f.1)	n.s.	*	n.s.	*
LAD	*	n.s.	n.s.	*
ABLAI (f.1)		*	n.s.	*
ABLAI (15DAF)		*	n.s.	n.s.
ABLAD		*	n.s.	*
harvest index	*	n.s.	n.s.	n.s.

Table 2. Summary of analyses of variance for all variables (continued)

	Within *Brassica napus* L. (1979)	Within *Brassica napus* L. (1980)	Within *Brassica campestris* L. (1980)	Between Species (1980)
plant density	*	n.s.	n.s.	n.s.
% seed yield per main raceme	*	-	-	
seed yield	n.s.	n.s.	n.s.	*

n.s., * - non-significant and significant respectively, at $p \leq .05$.

Significant differences occurred between genotypes of *B. campestris* L. (S.T.) for only LER (tl.1 to se.0), $\overline{\text{RGR}}$ (TOS to f.1) and $\overline{\text{RGR}}$ (TOS to m.1) (Table 2). There were no significant differences for all other variables.

Three genotypes of *B.napus* L. (i.e., Oro, Regent, 74G-1382) had significant differences for tl.5, abl.1, stl.1, f.1, etl.0, m.1, SEP, LER (tl.1 to f.1), CDW (f.1), CDW (15DAF), $\overline{\text{CGR}}$ (TOS to f.1), $\overline{\text{RGR}}$ (TOS to f.1), $\overline{\text{RGR}}$ (f.1 to m.1), $\overline{\text{RGR}}$ (TOS to m.1), and LAI (f.1) (Tables 2, 3, 4 and 5). Similarily, no significant differences for tl.1, SFP, and seed yield were indicated in either year (Tables 2, 3, 4 and 5). Results were inconsistent for tl.3, tl.7, se.0, LER (tl.1 to se.0), LER (se.0 to f.1), CDW(m.1), $\overline{\text{CGR}}$ (f.1 to m.1), $\overline{\text{CGR}}$ (TOS to m.1), LAI (15DAF), $\overline{\text{ULR}}$, $\overline{\text{LAR}}$, LAD, harvest index and plant density.

True Leaf Growth Stages

In 1979, 74G-1382 was significantly earlier in reaching tl.3 than all other genotypes, and significantly earlier than Regent in reaching tl.7 (Table 3). The cultivar Oro reached tl.5 and tl.7 significantly earlier than all other genotypes. No significant differences were found for number of days to tl.1.

B. campestris L. was significantly earlier than *B. napus* L. in reaching all true leaf stages in 1980 (Table 4). The largest difference occurred at tl.3 where *B. campestris* L. was approximately ten days earlier than

Table 3. Means for leaf growth stages (days) (1979)

	tl.1	tl.3	tl.5	tl.7
Oro	17.0a	24.0b	31.5a	38.0a
Regent	18.2a	24.5b	34.5b	42.0c
1382	17.0a	23.2a	34.0b	40.0b

a-values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

B. napus L.

In 1980, Tower was significantly later in reaching tl.1 and tl.3 than all other genotypes (Table 4). Oro was significantly earlier in reaching tl.5 than all other genotypes and significantly earlier than Tower, 75G-1999B and 75G-2180 in reaching tl.7.

For growth stages tl.1, tl.3,tl.5 and tl.7, there were no significant differences between genotypes of *B. campestris* L. (Table 4).

In both years the three genotypes of *B. napus* L. (Oro, Regent, 74G-1382) indicated a similar growth pattern. However, in 1979 there were significant differences among these three genotypes for tl.3 and tl.7, while in 1980 no significant differences were indicated among genotypes at these true leaf stages.

Table 4. Means for leaf growth stages (days) (1980)

	tl.1	tl.3	tl.5	tl.7
B. napus L.	13.8*	27.3*	35.0*	38.8*
B. camp. L.	13.0	16.8	25.8	33.7
Oro	13.0a	24.5a	32.5a	36.5a
Regent	14.5a	27.5ab	35.0b	39.0abc
1382	13.0a	26.0bc	35.0b	39.0abc
1999B	13.5a	27.5ab	36.0b	40.5c
2180	13.5a	27.5ab	36.0b	40.0bc
908	13.0a	25.5ab	34.5c	37.0a
Altex	14.0a	28.5b	34.5b	37.5ab
Tower	16.0b	31.5c	36.5b	41.0c
Candle	13.0a	16.0a	25.0a	34.5a
Torch	13.0a	17.5a	26.5a	33.0a

* - Species means significantly different at $p \leq 0.05$.
a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Onset of Stem Elongation

There were no significant differences among genotypes of *B. napus* L. for se.0 in 1979 (Table 5).

B. napus L. was significantly earlier in reaching se.0 than *B. campestris* L. (Table 6).

In 1980; 75G-2180, 74G-1382, 75G-908, and 75G-1999B were all significantly earlier in reaching se.0 than either Tower or Regent (Table 6).

There were no significant differences between genotypes of *B. campestris* L. for se.0 (Table 6).

In 1979, no significant differences among Oro, Regent and 74G-1382 occurred. However, in 1980, Regent was significantly later for se.0 than 74G-1382.

First Axillary Branch Leaf

The line 74G-1382 was significantly earlier than Regent, which was significantly earlier than Oro in 1979 (Table 5).

B. campestris L. was significantly earlier for abl.1 than *B. napus* L. (Table 6).

In 1980, Oro was significantly later in reaching abl.1 than all other genotypes (Table 6).

There were no significant differences between genotypes of *B. campestris* L. for abl.1 (Table 6).

In 1979 and 1980, 74G-1382 was significantly earlier for abl.1 than cultivar Oro. There was no significant difference between 74G-1382 and Regent in 1980; however, in

Table 5. Means for Growth Stages (days) (1979)

	se.0	abl.1	stl.1	f.1
Oro	31.0a	58.5c	50.0c	61.0c
Regent	31.5a	54.0b	48.5b	57.0b
1382	30.0a	46.0a	47.0a	51.5a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

1979 74G-1382 was significantly earlier for abl.1 than Regent.

First True Leaf Senesced

For stl.1 in 1979, 74G-1382 reached stl.1 significantly earlier than Regent, which was significantly earlier than cultivar Oro (Table 5).

B. campestris L. was significantly earlier for stl.1 than *B. napus* L. (Table 6).

In 1980, Oro, Regent and Tower were significantly later than all other genotypes (Table 6).

Candle and Torch of *B. campestris* L. were not significantly different for stl.1 (Table 6).

In both years, 74G-1382 was significantly earlier than either Oro or Regent in reaching stl.1.

Table 6. Means for growth stages (days) (1980)

	se.0	abl.1	stl.1	f.1
B. napus L.	29.6*	40.7*	48.1*	55.4*
B. camp. L.	32.0	37.0	43.0	46.5
Oro	30.5bc	50.0b	50.5b	63.0d
Regent	32.5c	40.0a	50.0b	57.0bc
1382	28.0ab	39.0a	45.5a	52.0a
1999B	29.0ab	39.5a	46.5a	53.0a
2180	27.5a	39.0a	47.5a	55.0abc
908	28.0ab	39.0a	46.5a	51.0a
Altex	29.5ab	39.0a	47.5a	54.0ab
Tower	32.0c	40.0a	50.5b	58.0c
Candle	32.0a	37.0a	43.5a	47.0a
Torch	32.0a	37.0a	42.5a	46.0a

* - Species means significantly different at $p \leq 0.05$.
a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

First flower

Among genotypes of *B. napus* L. in 1979, the experimental line, 74G-1382 was significantly earlier than Regent, which was significantly earlier than Oro (Table 5). 74G-1382 flowered approximately ten days ahead of the cultivar Oro.

B. campestris L. was significantly earlier in reaching f.1 than *B. napus* L. (Table 6). The difference was approximately nine days.

In 1980; Oro, Regent and Tower were significantly later than 74G-1382, 75G-1999B and 75G-908 for f.1 (Table 6). The time between the earliest flowering genotype and the latest flowering genotype spanned approximately twelve days.

There were no significant differences between genotypes of *B. campestris* L. for first flower (Table 6).

In both years, Oro, Regent and 74G-1382 had the same ranking for first flower.

End of True Leaves

For etl.0 in 1979, 74G-1382 was significantly earlier in reaching etl.0 than all other genotypes (Table 7).

B. campestris L. reached etl.0 significantly earlier than *B. napus* L. (Table 8).

In 1980, Oro, Regent and Tower, were significantly later than 74G-1382 in reaching etl.0 (Table 8).

There were no significant differences between genotypes of *B. campestris* L. (Table 8).

Table 7. Means for growth stages and growth periods (days) (1979)

	etl.0	m.1	SEP	SFP
Oro	106.5b	113.0c	30.0c	52.0a
Regent	104.5b	109.0b	25.5b	52.0a
1382	96.0a	103.0a	21.5a	51.5a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

In both years Oro, Regent and 74G-1382 had the same ranking for days to end of true leaves.

Maturity of First Pod

For days to maturity of first pod, 74G-1382 was significantly earlier than Regent, which was significantly earlier than Oro in 1979 (Table 7).

In 1980, *B. campestris* L. was significantly earlier in reaching m.1 than *B. napus* L. (Table 8). The difference was approximately fourteen days.

For maturity of first pod, 74G-1382 and 75G-908, were both significantly earlier than Oro, Regent and Tower in 1980 (Table 8). There was approximately ten days difference between the earliest and latest maturing genotypes.

There was no significant difference between genotypes of *B. campestris* L. for maturity of first pod (Table 8).

Table 8. Means for growth stages and growth periods (days) (1980)

	etl.0	m.1	SEP	SFP
B. napus L.	101.4*	109.4*	25.8*	59.9*
B. camp. L.	88.0	95.0	14.5	48.5
Oro	108.0c	115.0c	32.5b	52.0a
Regent	104.0bc	111.0b	24.5a	54.0a
1382	96.0a	106.0a	24.0a	54.0a
1999B	100.0ab	108.0ab	24.0a	55.0a
2180	99.0ab	108.0ab	27.5a	53.0a
908	101.0ab	107.0a	23.0a	56.0a
Altex	100.0ab	108.0ab	24.5a	54.0a
Tower	103.0bc	111.0b	26.0a	53.0a
Candle	87.0a	96.0a	15.0a	49.0a
Torch	89.0a	94.0a	14.0a	48.0a

* - Species means significantly different at $p \leq 0.05$
a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Maturity rankings were the same for genotypes 74G-1382, Regent and Oro in both 1979 and 1980.

Stem Elongation Period

The stem elongation period of 74G-1382 was significantly shorter than that of Regent, which was significantly shorter than that of Oro in 1979 (Table 7).

B. campestris L.had a significantly shorter stem elongation period than *B. napus* L. in 1980 (Table 8). The difference was approximately eleven days.

In 1980, Oro had a significantly longer stem elongation period than all other genotypes of *B. napus* L. (Table 8). Apart from Oro, there were no other significant differences among genotypes.

There were no significant differences between genotypes of *B. campestris* L. for stem elongation period in 1980 (Table 8).

In both years, Oro had a significantly longer stem elongation period than either Regent or 74G-1382. The difference between the shortest and longest stem elongation period among these genotypes in both 1979 and 1980 was 8.5 days.

Seed Formation Period

There were no significant differences among genotypes of *B. napus* L. in 1979 (Table 7).

B. napus L. had a significantly longer seed formation period then *B. campestris* L. (Table 8). The SEP of *B. napus* L. was approximately eleven days longer than *B. campestris* L., but the SFP only 5.5 days longer.

There were no significant differences among genotypes of *B. napus* L. for seed formation period in 1980 (Table 8).

Genotypes of *B. campestris* L. demonstrated no significant differences for seed formation period (Table 8).

In both years; Oro, Regent and 74G-1382 did not differ significantly for SFP. The length of the seed formation period among these three genotypes varied by only 2.5 days.

Leaf Emergence Rate

In each period analysed, the later maturing Oro had a significantly higher leaf emergence rate than either Regent or 74G-1382 in 1979 (Table 9).

From tl.1 to f.1, Regent had a significantly greater leaf emergence rate than 74G-1382. After attainment of tl.1, Oro developed a new leaf approximately every fourth day, whereas 74G-1382 required five days to develop a new leaf.

B. campestris L. had a significantly higher leaf emergence rate than *B. napus* L. during all periods analysed (Table 10).

In 1980, differences among genotypes of *B. napus* L. for leaf emergence rate were significant for only the period from tl.1 to f.1 (Table 10). During this period, Oro had a significantly higher leaf emergence rate than all other

Table 9. Means for leaf emergence rates (leaves/plant/day) (1979)

	tl.1 to se.0	se.0 to f.1	tl.1 to f.1
Oro	0.28b	0.24b	0.26c
Regent	0.24a	0.19a	0.22b
74G-1382	0.23a	0.16a	0.20a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Table 10. Means for leaf emergence rates (leaves/plant/day) (1980)

	tl.1 to se.0	se.0 to f.1	tl.1 to f.1
B. napus L.	0.13*	0.23*	0.23*
B. camp. L.	0.21	0.28	0.29
Oro	0.14a	0.27a	0.28c
Regent	0.15a	0.22a	0.24b
1382	0.10a	0.20a	0.18a
1999B	0.12a	0.22a	0.21b
2180	0.11a	0.24a	0.22b
908	0.13a	0.26a	0.24b
Altex	0.11a	0.21a	0.22b
Tower	0.15a	0.24a	0.24b
Candle	0.18a	0.28a	0.27a
Torch	0.24b	0.29a	0.30b

* - Species means significantly different at $p \leq 0.05$.
a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

genotypes, whereas 74G-1382 had a significantly lower leaf emergence rate than all other genotypes. Leaf emergence rates during the stem elongation period were approximately double those during tl.1 to se.0.

There were significant differences between genotypes of *B. campestris* L. for leaf emergence rate (Table 10). Torch had a significantly higher emergence rate than Candle during these periods.

In both years, Oro, Regent and 74G-1382 followed a similar pattern for leaf emergence rate during the period tl.1 to f.1. In 1980, no significant differences among these genotypes for leaf emergence rate were evident during the stem elongation period and tl.1 to se.0. However, in 1979, Oro had a significantly higher leaf emergence rate than Regent and 74G-1382 during these periods.

Crop Dry Weight

Oro had a significantly greater crop dry weight than 74G-1382 at f.1, 15DAF, and m.1 in 1979 (Table 11).

Regent was significantly greater than 74G-1382 at f.1 and 15DAF, but at m.1 the difference between these two genotypes were not significant.

B. napus L. had a significantly greater crop dry weight than B. campestris L. at f.1, 15DAF and m.1 (Table 12). The largest difference occurred at 15DAF, where *B. napus* L. was approximately 107 grams heavier than *B. campestris* L.

Table 11. Means for crop dry weights (grams) (1979)

	f.1	15DAF	m.1
Oro	219.2b	325.2b	530.7b
Regent	206.6b	326.3b	451.7a
1382	113.7a	237.2a	439.5a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Table 12. Means for crop dry weights (grams) (1980)

	f.1	15DAF	m.1
B. napus L.	95.2*	248.0*	222.1*
B. camp. L.	46.4	141.3	168.9
Oro	173.7d	359.7d	258.0a
Regent	99.7c	263.8c	210.6a
1382	66.7ab	198.9ab	214.5a
1999B	82.6bc	229.6bc	236.4a
2180	95.0c	246.4c	225.0a
908	55.9a	181.4a	224.3a
Altex	92.2c	252.7c	191.5a
Tower	96.0c	251.3c	216.1a
Candle	43.5a	127.0a	158.2a
Torch	49.3a	155.5a	179.5a

* - Species means significantly different at $p \leq 0.05$.
a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

In 1980, there were significant differences among genotypes of *B. napus* L. for crop dry weight at f.1 and 15DAF; however no significant difference occurred at m.1 (Table 12). Oro was significantly greater for crop dry weight at f.1 and 15DAF than all other genotypes At f.1, 75G-908 and 74G-1382 had significantly smaller crop dry weights than all other genotypes except 75G-1999B. The crop dry weight at f.1 of 75G-908 and 74G-1382 were approximately one-third of Oro.

There were no significant differences between genotypes of *B. campestris* L. (Table 12).

In 1979 and 1980, Oro had a significantly greater crop dry weight at f.1 and 15DAF than 74G-1382. However, in 1979, Oro had a significantly greater crop dry weight at m.1 than both Regent and 74G-1382, whereas in 1980 no significant differences were detected among these three genotypes.

Mean Crop Growth Rate

From seeding to f.1, Oro and Regent had a significantly higher $\overline{\text{CGR}}$ than did 74G-1382, while from f.1 to m.1, Oro and 74G-1382 were significantly higher than Regent (Table 13). From seeding to m.1, Oro was significantly higher than either Regent or 74G-1382.

Table 13. Means for mean crop growth rates (grams/day)

(1979)

	seeding to f.1	f.1 to m.1	seeding to m.1
Oro	3.59b	5.99b	4.70b
Regent	3.62b	4.71a	4.14a
1382	2.21a	6.33b	4.27a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

B. napus L. had a significantly greater $\overline{\text{CGR}}$ from seeding to f.1 than did *B. campestris* L. (Table 14). There were no significant differences between species for $\overline{\text{CGR}}$ from f.1 to m.1 and seeding to m.1.

Oro had a significantly higher $\overline{\text{CGR}}$ than all other genotypes from seeding to f.1 in 1980(Table 14). No significant differences were indicated for $\overline{\text{CGR}}$ from f.1 to m.1, or from seeding to m.1.

There were no significant differences between genotypes of *B. campestris* L. (Table 14).

In 1979 and 1980, both Oro and Regent had significantly higher $\overline{\text{CGR}}$s from seeding to f.1 than did 74G-1382. Differences among these three genotypes for $\overline{\text{CGR}}$ from f.1 to m.1 and seeding to m.1 were significant in 1979, but not in 1980.

Table 14. Means for crop growth rates (grams/day) (1980)

	seeding to f.1	f.1 to m.1	seeding to m.1
B. napus L.	1.69*	2.35*	2.03*
B. camp. L.	1.00	2.53	1.78
Oro	2.75d	1.62a	2.24a
Regent	1.75c	2.05a	1.90a
1382	1.28ab	2.73a	2.02a
1999B	1.56bc	2.79a	2.19a
2180	1.73c	2.45a	2.08a
908	1.09a	3.00a	2.10a
Altex	1.70c	1.84a	1.77a
Tower	1.65c	2.27a	1.94a
Candle	0.92a	2.34a	1.64a
Torch	1.07a	2.71a	1.91a

* - Species means significantly different at $p \leq 0.05$.

a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Mean Relative Growth Rate

In all growth periods, the $\overline{RGR}$ of 74G-1382 was significantly greater than that of all other genotypes in 1979 (Table 15).

B. campestris L. had a significantly higher $\overline{RGR}$ than *B. napus* L. over all growth periods analysed in 1980 (Table 16).

Oro, Regent and Tower had a significantly lower $\overline{RGR}$ from seeding to f.1 than all other genotypes in 1980 (Table 16). From f.1 to m.1, 75G-908 had a significantly higher $\overline{RGR}$ than Oro, Regent, Altex and Tower. From seeding to m.1, Oro, had a significantly lower $\overline{RGR}$ than did 74G-1382, 75G-1999B, 75G-2180, 75G-908 and Altex.

Table 15. Means for mean relataive growth rates (grams/gram/day) (1979)

	seeding to f.1	f.1 to m.1	seeding to m.1
Oro	.183a	.017a	.107a
Regent	.195b	.015a	.109b
74G-1382	.204c	.027b	.115c

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Table 16. Means for relative growth rates (grams/gram/day) (1980)

	seeding to f.1	f.1 to m.1	seeding to m.1
B. napus L.	.186*	.016*	.102*
*B. camp.*L.	.207	.027	.115
Oro	.174a	.008a	.099a
Regent	.183b	.014ab	.100ab
1382	.192c	.022bc	.105c
1999B	.193c	.019bc	.104c
2180	.188c	.016ab	.104c
908	.192c	.025c	.105c
Altex	.191c	.103ab	.102bc
Tower	.179b	.015ab	.101ab
Candle	.204a	.026a	.113a
Torch	.211b	.027a	.117b

* - Species means significantly different at $p \le 0.05$.

a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \le 0.05$.

Table 17. Means for leaf area indexes (m^3, mean unit leaf rate (grams/m^3/day) and mean leaf area ratio (m^2/gram (1979)

	LAI f.1	LAI 15DAF	$\overline{\text{ULR}}$ seeding to f.1	$\overline{\text{LAR}}$ seeding to f.1
Oro	3.22b	3.22b	38.06a	.0038a
Regent	2.99b	3.09b	39.67a	.0040a
1382	2.03a	2.37a	35.06a	.0035a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

There were significant differences between genotypes of *B. campestris* L. for $\overline{\text{RGR}}$ from seeding to f.1 and from seeding to m.1 (Table 16). Torch had a significantly higher $\overline{\text{RGR}}$ than Candle during both of these growth periods. From f.1 to m.1, no significant differences between genotypes of *B. campestris* L. were detected.

In both 1979 and 1980 and over all growth periods, 74G-1382 had a significantly higher $\overline{\text{RGR}}$ than did Oro.

Leaf area index

Oro and Regent were significantly larger than 74G-1382 at both f.1 and 5DAF in 1979 (Table 17).

B. napus L. had a significantly greater LAI at f.1 and 15DAF than did *B. campestris* L. (Table 18).

There were significant differences among genotypes of *B. napus* L. for LAI at f.1, but not at 15DAF in 1980 (Table 18). Oro and Tower had significantly higher LAI's at f.1 than did 74G-1382.

There were no significant differences in LAI between genotypes of *B. campestris* L. (Table 18).

In 1979, Oro and Regent had significantly greater LAI's at f.1 and 15DAF than did 74G-1382, whereas in 1980 no significant differences were detected among these three genotypes.

Table 18. Means for leaf area indexes (m^2, mean unit leaf rate (grams/m^2/day) and mean leaf area ratio (m^2/gram) (1980)

	LAI f.1	LAI 15DAF	$\overline{\text{ULR}}$ seeding to f.1	$\overline{\text{LAR}}$ seeding to f.1
B. napus L.	6.89*	6.90*	16.38*	.0098*
*B. camp.*L	4.56	4.70	14.44	.0124
Oro	7.84b	7.20a	23.70c	.0057a
Regent	6.46ab	6.54a	18.28b	.0081b
1382	5.46a	5.73a	15.59ab	.0106bc
1999B	7.14ab	7.47a	14.79ab	.0109bc
2180	7.70ab	7.70a	15.19ab	.0102bc
908	5.87ab	6.36a	12.27a	.0136c
Altex	6.85ab	7.00a	16.62b	.0094b
Tower	7.78b	7.17a	14.59ab	.0102bc
Candle	4.60a	4.70a	13.30a	.0133a
Torch	4.52a	4.72a	15.58a	.0116a

* - Species means significantly different at $p \leq 0.05$.

a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Mean unit leaf rate

There were no significant differences among genotypes of *B. napus* L. for $\overline{\text{ULR}}$ in 1979 (Table 17).

B. napus L. had a significantly greater $\overline{\text{ULR}}$ from seeding to f.1 than did *B. campestris* L. (Table 18).

Oro had a significantly greater $\overline{\text{ULR}}$ than all other genotypes in 1980 (Table 18). The experimental line, 75G-908, had a significantly smaller $\overline{\text{ULR}}$ than did Oro, Altex and Regent.

There were no significant differences in $\overline{\text{ULR}}$ between genotypes of *B. campestris* L. (Table 18).

In 1980, Oro was significantly greater than 74G-1382 and Regent for $\overline{\text{ULR}}$ whereas in 1979 no significant differences were detected among these three genotypes.

Mean leaf area ratio

There were no significant differences among genotypes of *B. napus* L. for $\overline{\text{LAR}}$ in 1979 (Table 17).

B. napus L. had a significantly greater $\overline{\text{LAR}}$ from seeding to f.1 than did *B. campestris* L. (Table 18).

The experimental line, 75G-908, had a signifcantly higher $\overline{\text{LAR}}$ than Oro, Regent and Altex in 1980 (Table 18). Oro had a significantly lower $\overline{\text{LAR}}$ than all other genotypes.

There were no significant differences between genotypes of *B. campestris* L. for $\overline{\text{LAR}}$ in 1980 (Table 18).

In 1979, no significant differences were detected among Oro, Regent and 74G-1382 for $\overline{\text{LAR}}$, whereas in 1980, Oro had a significantly lower $\overline{\text{LAR}}$ than Regent or 74G-1382.

Leaf area duration

Oro and Regent had significantly higher LAD's than did 74G-1382 in 1979 (Table 19).

B. napus L. had a significantly greater LAD than did *B. campestris* L. (Table 20).

There were no significant differences among genotypes of *B. napus* L. for LAD in 1980 (Table 20).

There were no significant differences between genotypes of *B. campestris* L. (Table 20).

In 1979, both Oro and Regent were significantly larger than 74G-1382 for LAD, whereas in 1980, no significant differences were detected among these three genotypes.

Axillary branch leaf area index

B. napus L. had a significantly greater ABLAI at f.1 than did *B. campestris* L. (Table 20). THere were no significant differences between species for ABLAI at 15DAF.

At f.1, Oro had a significantly lower ABLAI than either 75G-2180 or Tower in 1980(Table 20). At 15DAF, 75G-2180 had a significantly higher ABLAI than did Oro.

There were no significant differences between genotypes of *B. campestris* L. for ABLAI at f.1 or 15DAF (Table 20).

Table 20. Means for leaf area duration (m^2 days), axillary branch leaf area index (m^2) and axillary branch leaf area duration (m^2 days) (1980)

	LAD f.1 to m.1	ABLAI f.1	ABLAI 15DAF	ABLAD f.1 to m.1
B. napus L.	65.2*	1.36*	2.20	26.2*
B. camp. L.	39.7	.92	1.88	15.5
Oro	62.8a	0.92a	1.28a	14.2a
Regent	63.2a	1.24ab	1.96ab	21.9ab
1382	55.0a	1.16ab	2.00ab	32.7b
1999B	72.6a	1.24ab	2.08ab	22.7ab
2180	70.0a	1.88c	2.88b	42.0c
908	63.3a	1.20ab	2.40ab	25.3ab
Altex	65.8a	1.48abc	2.52ab	26.8b
Tower	69.0a	1.72bc	2.40ab	23.9ab
Candle	39.1a	1.12a	1.92a	15.3a
Torch	40.2a	.76a	1.88a	15.7a

* - Species means significantly different at $p \leq 0.05$.

a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Table 19. Means for leaf area duration (m^2 days) (1979)

	f.1 to m.1
Oro	57.1b
Regent	56.1b
1382	44.9a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

Axillary branch leaf area duration

B. napus L. had a significantly greater ABLAD than did *B. campestris* L. (Table 20).

The line, 75G-2180, had a significantly larger ABLAD than all other genotypes in 1980 (Table 20).

There were no significant differences in ABLAD between genotypes of *B. campestris* L. (Table 20).

Plant density

Regent had a significantly higher plant density than 74G-1382, which in turn was significantly greater than the cultivar Oro (Table 21).

Table 21. Means for plant density (#plants/0.5m^2), harvest index, seed yield (gms/0.5m^2) and percentage of seed yield derived from the main raceme (1979)

	plant density	harvest index	seed yield	% seed yield per main raceme
Oro	54.4a	.30ab	129.6a	66b
Regent	67.1c	.31b	115.3a	63b
1382	58.4b	.28a	113.0a	50a

a - Values in the same column with the same letter are not significantly different, SNK Test $p \leq 0.05$.

There were no significant differences between species in 1980 (Table 22).

There were no significant differences among genotypes of *B. napus* L. for plant density in 1980 (Table 22).

There were no significant differences between genotypes of *B. campestris* L. for plant density in 1980 (Table 22).

Harvest index

Regent had a significantly greater harvest index than did 74G-1382 in 1979 (Table 21).

There were no significant differences in harvest index between species in 1980 (Table 22).

Table 22. Means for plant density (#plants/0.25m²), harvest index, and seed yield (gms/0.25m²) (1980)

	plant density	harvest index	seed yield
B. napus L.	29.6	.20	69.6*
B. camp.L.	28.4	.22	46.0
Oro	32.4a	.16a	59.4a
Regent	26.3a	.20a	73.0a
1382	27.0a	.21a	57.4a
1999B	32.1a	.23a	92.5a
2180	30.7a	.20a	66.9a
908	25.3a	.21a	73.3a
Altex	30.4a	.20a	64.7a
Tower	32.3a	.20a	70.0a
Candle	28.4a	.24a	43.7a
Torch	28.4a	.21a	48.3a

* - Species means significantly different at $p \leq 0.05$.

a - Values in the same column within each species with the same letter are not significantly different, SNK Test $p \leq 0.05$.

There were no significant differences among genotypes of *B. napus* L. for harvest index in 1980 (Table 22).

There were no significant differences between genotypes of *B. campestris* L. for harvest index in 1980 (Table 22).

Seed yield per main raceme

There were significant differences among genotypes of *B. napus* L. for seed yield per main raceme in 1979 (Table 21). Oro derived 66% of its seed yield from the main raceme, whereas 74G-1382 only derived 50% of its seed yield from the main raceme.

Seed yield

There were no significant differences for seed yield among genotypes of *B. napus* L. in 1979 (Table 21).

B. napus L. had a significantly higher seed yield than did *B. campestris* L. (Table 22). *B. napus* L. yielded 1 1/2 times that of *B. campestris* L.

There were no significant differences for seed yield among genotypes of *B. napus* L. in 1980 (Table 22).

There were no significant differences between genotypes of *B. campestris* L. for seed yield (Table 22).

V. DISCUSSIONS AND SUMMARY

B. campestris L. vs *B. napus* L.

B. campestris L. reached all growth stages except se.0 significantly earlier than *B. napus* L. and had significantly higher leaf emergence rates during all growth periods. This pattern is in contrast to that among genotypes of *B. napus* L. where early maturing genotypes with early f.1 and early subsequent growth stages had significantly lower leaf emergence rates than did later maturing genotypes. *B. napus* L. had significantly longer growth periods (i.e., SEP and SFP), greater crop dry weights and higher $\overline{\text{CGR}}$s than *B. campestris* L. However, *B. campestris* L. had significantly greater $\overline{\text{RGR}}$s over all growth periods and could be considered as being more efficient in producing dry material.

The significantly greater reproductive potential of *B. napus* L., established during vegetative growth, was evidenced by greater crop dry weight at f.1. The superior assimilatory potential during seed filling (i.e., LAD and ABLAD) of *B. napus* L. was available to meet the demands necessitated by reproductive requirements. These factors - reproductive potential and assimilatory potential during seed filling - were important in leading to significantly higher seed yield in *B. napus* L. than in *B. campestris* L..

Genotypes of *B. campestris* L.

Between genotypes of *B. campestris* L., very few characters indicated significant differences, and those differences were small. The two genotypes are the only commonly grown cultivars in western Canada.

Genotypes of *B. napus* L.

The seedling period extends from the emergence of the cotyledons to the unfolding of the first true leaf (tl.1). In the event that more frequent observations were conducted and more replications grown, better estimates of tl.1 would have been obtained. The time taken to reach tl.1 may be viewed as a measure of the velocity of the germination process, or in effect a measure of cold tolerance, since temperature is one of the major environmental factors affecting germination.

There was a tendency for later maturing genotypes to be earlier in reaching true leaf growth stages. This distinction was most noticeable at tl.5, where Oro was significantly earlier than other genotypes in both years.

The determination of initiation of se.0 is much more difficult than other growth stages. It appears that the differences between genotypes for se.0 are much more difficult to detect due primarily to the subjectivity employed in making the observation and to the rapidity with which stem elongation occurs. Earlier maturing genotypes of *B. napus* L. in 1980, tended to be earlier for se.0. In describing the stages of organogenesis in *B. napus* L. (W.T.), at the time of flower initiation, the meristems produce cells which differentiate into floral buds where before they were forming leaf buds (Fabry, 1979). The date of commencement of stem elongation is regarded as an approximation of the time of floral induction. Total plant dry weight of *B. napus* L. (W.T.) at the time of floral initiation is linked to the final yield or a threshold value (Fabry, 1979). Below this threshold it is the production potential which is limited and is correlated with the dry matter present in the plant at the time of onset of stem elongation. Above this threshold there occurs the phenomenon of competition within the plant and between plants which restrict the yield potential of the plant.

The earliest maturing genotype was significantly earlier in reaching abl.1, stl.1, f.1, etl.0, and m.1 than the latest maturing genotype. This represents a reversal in trends from that indicated for true leaf growth stages. The leaf emergence rate from tl.1 to f.1 was significantly greater for the late maturing genotype than the earlier maturing genotypes. These results are similar to those which indicated that the cultivar Target (*B. napus* L.) exhibited many characteristics which would tend to make it a late cultivar (e.g., lower leaf emergence rate during the pre-anthesis period); however it was significantly earlier in days to first flower and maturity (Campbell *et al*., 1978).

In 1980, when there was an exceptionally dry environment until approximately thirty days after seeding, the leaf emergence rate from tl.1 to se.0 of *B. napus* L. genotypes was approximately one-half the leaf emergence rate in 1979, when moisture was not a limiting factor. However, leaf emergence rate in both years from tl.1 to f.1 was almost identical for those genotypes of *B. napus* L. that were analyzed in both years.

In both years, genotypes of *B. napus* L. that were early maturing were also significantly earlier in reaching f.1. This concurs with other studies, which have found that days to first flower is a major factor in determining the time to maturity in annual rapeseed species (Campbell *et al*., 1978). The heritabilities for f.1 ranged from 21% to 61% in crosses between three cultivars of *B. napus* L., while for m.1 they ranged from 16% to 36% (Campbell *et al*., 1978). This indicates that selection for first flower could result in better genetic gains for early maturity.

By definition, first flower determines the duration of the vegetative period and also appears to affect the duration of subsequent reproductive periods (Campbell and Kondra, 1977, 1978). The relative importance of the vegetative period and reproductive period in determining final economic yield, is not fixed, but varies with the genotype, the agronomic treatments imposed, and environmental conditions.

Both annual rapeseed species exhibit axillary and sequential flowering in contrast to the terminal and synchronous flowering of cereals. Therefore, large discrepancies in time of maturity exist at the inter-inflorescence level, but we can assume they are just as great at the intra-inflorescence level. In the field, rapeseed flowers over an extended period and the decision when to harvest must be a compromise between allowing maximum yield development, particularly in later maturing seeds on the lower racemes, and avoidance of excessive seed loss through shattering of early ripening pods. Since the majority of seed yield comes from the terminal inflorescence, a random sample of crop plants should be examined primarily on seed development within the terminal inflorescence to determine optimum harvesting time.

There were significant differences among genotypes of *B. napus* L. for SEP in both years, whereas for SFP no significant differences were detected. In another study among genotypes of *B. napus* L., at any given seeding date, the genotype with the shortest pre-anthesis period had the highest seed yield, while over all seeding dates, an individual genotype produced a higher seed yield from the longer pre-anthesis period (Degenhardt and Kondra, 1981b). This indicates the importance of maximizing reproductive potential as it relates to an optimal developmental pattern of a particular genotype to its environment. The fact that early maturity is not necessarily associated with a reduction in seed yield is particularly obvious since the early maturing genotypes were not significantly lower yielding than the later maturing genotypes.

Crop dry weight was significantly greater for later maturing than earlier maturing genotypes of *B. napus* L. at f.1 and 15DAF in both years. However, only in 1979 were there any significant differences among genotypes of *B. napus* L. for crop dry weight at m.1. The relationship between crop dry weight and seed yield is inconsistent, since the greater reproductive potential of late maturing genotypes is often not realized in higher seed yields. Seed yield is directly affected by the assimilatory potential during seed filling, length of SFP and prevailing climatic variables during seed formation and filling. For example, if adverse environmental conditions prevail during intensive dry matter accumulation in the seeds, the reproductive potential established during the vegetative phase will not be realized.

The earlier maturing genotypes had significantly lower $\overline{CGR}$ from time of seeding to f.1 than the later maturing genotype. However, $\overline{CGR}$ from f.1 to m.1 amongst these genotypes, indicated no significant difference. This confirms an earlier conclusion, i.e., that while late maturing genotypes have significantly greater reproductive potential it is often limited by factors affecting seed filling.

In general, the genotypic rankings for $\overline{\mathrm{CGR}}$ were reversed from those for $\overline{\mathrm{RGR}}$ in both years. $\overline{\mathrm{RGR}}$ represents the efficiency of the crop in production of new material. The growth parameter, $\overline{\mathrm{CGR}}$, is more a measure of the size of the plant than a measure of velocity of growth, and therefore varies similarly with crop dry weight.

In both years the earlier maturing genotypes of *B. napus* L. had significantly greater $\overline{\mathrm{RGR}}$s over all growth periods analyzed than did the later maturing genotypes. Previous research indicates that the earlier maturing experimental lines have significantly outyielded the later maturing genotypes of *B. napus* L. (Campbell *et al*., 1978).

Later maturing genotypes of *B. napus* L. had significantly higher $\overline{\mathrm{ULR}}$s than did the earlier maturing genotypes in 1980. Earlier maturing genotypes of *B. napus* L. had significantly higher $\overline{\mathrm{LAR}}$s than did the later maturing genotypes in 1980. The usefulness of $\overline{\mathrm{ULR}}$ measured after anthesis becomes less meaningful because the true photosynthetic surface of rapeseed is underestimated (Major, 1975; Major and Charnetski, 1976). The importance of pods and stems in producing carbon assimilates (Brar and Thies, 1977; Major and Charnetski, 1976) results in a significant underestimation.

In1979, the later maturing cultivars of *B. napus* L. had significantly higher LAIs and LAD, whereas in 1980 the results were less clear. However, in 1980 there was a tendency for earlier maturing genotypes of *B. napus* L. to have higher ABLAIs than did later maturing genotypes. Further, in 1980 the earlier maturing genotypes of *B. napus* L. had significantly higher ABLADs than did the later maturing cultivars. The contribution that axillary branch leaves make to the accumulation of dry matter inthe seeds has not been researched. High-yielding genotypes of summer *B. napus* L. developed more pods, because it was able to maintain a better rate of supply of carbon assimilates to the pods when their number and the number of seeds they contain were being determined (Allen and Morgan, 1975). The low yielding variety had more unproductive, lower-positioned inflorescences, which would have drawn on the supply from the leaves that subtended them and which would have otherwise gone to the earlier developing pods carried on the higher positioned inflorescences. Axillary inflorescences depend for their supply of carbon assimilates on those they manufacture themselves; those which come from the leaves which subtend them and leaves inserted vertically below them. The contribution of assimilates to the developing seeds by axillary branch leaves plays a major role in final seed yield. The overwhelming evidence points to the maintenance of a large and photosynthetically efficient leaf area at anthesis and over the period when the number of seeds per pod is being fixed while minimizing the number of non-productive inflorescences. It is probable that a higher percentage of assimilates in axillary branch leaves are translocated to seeds than those produced in true leaves simply due to proximity.

There were no significant differences among genotypes of *B. napus* L. for plant density in 1980, while in 1979,small significant differences were detected. No further analysis or adjustment of variables that may be related to plant density was performed in this study, due to the expected complexity of that relationship and the confounding nature of such an analysis.

Seed yield differences among genotypes of *B. napus* L. were not significant in either year. These results are inconsistent with previous findings (Campbell *et al.*, 1978; Degenhardt and Kondra, 1981b), which found the earlier maturing genotypes gave the highest seed yield. The unusually long, favorable fall in 1979, compared with the adverse climatic conditions, which occurred during the same period in 1980, undoubtedly would have had a significant effect during seed formation in realization of reproduction potential.

Fifty per cent or more the seed yield per plant is derived from the terminal inflorescence. The first developed pods have a competitive advantage in attaining full development over the younger more apically positioned ones especially when the demand for assimilates is high. The later maturing genotypes derive a significantly greater proportion of their total seed yield per plant from the terminal inflorescence than do earlier maturing genotypes. This is due to the greater axillary leaves assimilatory potential during seed filling of earlier maturing genotypes, which allows for greater seed filling on axillary inflorescences.

In selecting earlier maturing, higher yielding genotypes, existing breeding programs are obtaining genotypes that have an ever increasing percentage of total leaf area made up from axillary branch leaves. This is advantageous since it coincides with seed filling and the axillary branch leaves are located in close proximity to the seeds. It is also evident that the earlier maturing genotypes are more efficient on a crop or per unit area basis in producing new plant material as indicated by higher $\overline{RGR}$s. The usefulness of mean relative growth rate as a selection tool in breeding programs warrants further examination. Given the grater growth efficiency of earlier maturing genotypes, they could be more productive at higher seeding rates than genotypes which are not as efficient. Plant breeders should also give special attention to minimizing the number of inflorescences and thus reducing the inefficiencies of wasted photosynthesis.

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APPENDICES

APPENDIX 1. MEAN DAILY TEMPERATURE (°C)

	1979					1980				
Date	May	June	July	Aug	Sept	May	June	July	Aug	Sept
1	1.2	16.2	14.6	20.3	15.8	13.7	12.9	15.8	17.2	9.2
2	0.7	18.6	13.9	17.5	17.7	18.6	13.4	17.0	14.4	10.2
3	2.6	17.4	14.2	12.1	15.1	10.8	12.4	16.5	10.5	11.1
4	2.1	17.0	17.9	14.6	15.1	12.6	10.6	17.0	13.5	11.9
5	1.9	14.7	20.9	17.3	12.0	10.7	9.8	13.9	10.4	14.9
6	4.4	8.3	23.3	16.2	13.2	9.3	7.3	10.8	14.4	16.6
7	6.1	11.2	19.8	16.6	12.3	10.7	8.7	15.6	11.9	7.8
8	6.0	11.3	18.7	15.7	14.1	12.0	14.2	18.4	12.4	9.3
9	8.9	13.5	20.5	15.4	11.4	9.9	17.0	17.6	13.8	13.8
10	10.0	15.0	17.5	18.4	11.2	9.4	18.7	17.8	13.8	13.8
11	10.7	18.9	14.7	17.9	8.7	8.7	17.5	15.8	12.6	11.0
12	10.1	17.8	13.5	15.5	11.0	10.5	15.6	14.1	13.0	7.5
13	10.7	11.8	12.3	13.1	13.7	11.1	16.8	15.4	14.4	6.8
14	11.3	9.4	15.2	15.3	18.8	11.2	16.3	16.0	17.2	8.7
15	11.7	11.7	17.5	17.2	19.7	12.4	17.7	15.9	14.4	5.7
16	6.9	12.2	20.4	18.8	15.8	13.4	18.9	13.8	14.8	6.1
17	9.6	15.8	22.8	20.0	14.1	16.4	14.6	12.5	13.5	4.4
18	10.4	17.4	24.7	19.6	16.2	17.2	14.3	11.8	13.0	3.7
19	8.8	16.5	25.8	18.0	12.6	15.1	16.6	10.4	14.4	7.7
20	10.4	14.0	23.2	20.0	13.1	16.0	16.2	13.5	11.9	8.0
21	10.4	14.2	20.5	17.0	12.4	12.0	17.6	18.1	11.0	4.0
22	13.6	15.3	18.5	16.7	12.2	15.3	15.4	20.1	11.5	4.6
23	19.0	15.7	16.4	18.1	12.8	12.5	14.0	18.5	11.6	8.8
24	18.7	12.6	14.6	13.1	13.9	8.4	14.3	13.2	8.2	3.1
25	17.5	15.8	15.3	14.5	15.3	7.5	13.7	14.9	8.8	7.3
26	20.2	18.2	18.5	14.5	13.4	8.6	16.4	16.5	11.3	7.4
27	14.0	20.0	19.6	18.2	12.9	7.0	12.3	17.0	11.0	9.0
28	7.0	21.0	21.4	17.1	11.7	8.9	14.0	16.1	8.9	11.4
29	9.1	23.4	15.0	15.3	9.9	7.6	12.6	16.5	10.6	15.2
30	8.6	21.1	16.8	16.5	11.5	5.5	13.3	14.8	11.8	11.3
31	13.1		20.8	18.2		8.9		16.3	10.4	
Monthly Mean	9.6	15.5	18.4	16.7	13.6	11.3	14.5	15.5	12.5	9.0

APPENDIX 2. HOURS OF SUNSHINE

	1979					1980				
Date	May	June	July	Aug	Sept	May	June	July	Aug	Sept
1						13.9	4.8	15.1	3.8	7.8
2						12.4	4.0	14.2	2.3	3.8
3						13.2	0.2	5.4	0.0	6.4
4						9.5	2.9	8.6	8.8	9.3
5						10.1	6.8	10.8	0.7	M
6						12.8	8.0	5.9	4.0	M
7						0.0	15.6	15.1	4.6	M
8						13.8	16.3	12.7	12.2	M
9						13.0	15.4	14.2	10.9	M
10						13.0	11.4	7.1	7.2	M
11						12.3	6.0	8.1	9.0	M
12						14.7	15.2	8.0	7.8	M
13						14.0	12.5	11.6	13.4	M
14						14.3	13.9	2.2	10.8	M
15						14.6	15.7	7.9	9.5	M
16						14.7	12.1	10.0	13.1	0.0
17						13.7	1.1	2.9	0.5	0.8
18						9.9	4.0	7.0	1.8	1.6
19						7.3	12.5	0.1	13.0	0.6
20						14.6	13.6	13.2	12.0	3.9
21						0.2	15.1	14.5	10.2	1.8
22						1.9	3.2	10.9	10.5	1.4
23						0.0	0.3	15.1	4.2	4.5
24						0.0	0.0	7.4	0.0	2.5
25						0.0	3.7	6.4	13.0	1.5
26						0.0	7.7	13.7	10.8	8.2
27						0.0	0.0	9.9	7.4	9.1
28						3.9	5.2	12.3	1.5	4.2
29						11.5	11.7	13.4	11.9	5.7
30						8.1	12.4	11.5	5.3	9.5
31						11.8	-	-	7.1	-
						279.2	251.3	307.7	227.3	M
						286.0	291.2	316.0	292.5	187.3

APPENDIX 3. DAILY PRECIPITATION (mm)

	1979					1980				
Date	May	June	July	Aug	Sept	May	June	July	Aug	Sept
1	TR	0.2	28.6	-	-	3.6	15.0	-	-	TR
2	2.0	0.2	16.1	-	0.4	-	2.4	TR	13.3	TR
3	1.5	5.9	-	6.7	TR	-	17.8	20.2	36.7	TR
4	6.9	TR	-	0.2	1.0	-	2.8	-	0.2	
5	0.3	0.8	-	0.7	-	-	8.4	8.6	TR	
6	-	5.5	-	0.4	-	3.4	0.4	1.8	-	
7	-	-	3.0	-	-	TR	-	-	TR	6.4
8	-	1.8	TR	25.89	1.2	-	-	-	TR	-
9	-	TR	-	-	5.8	-	-	-	-	-
10	0.6	TR	3.0	-	1.8	-	-	TR	2.4	
11	TR	TR	48.4	0.2	0.2	-	3.1	TR	-	
12	-	-	17.9	0.8	-	-	-	1.8	2.4	1.4
13	-	9.2	10.5	-	-	-	-	TR	-	12.3
14	TR	29.9	4.8	-	-	-	-	2.8	2.4	1.4
15	TR	2.0	-	-	-	-	-	10.2	TR	2.1
16	19.7	TR	-	-	TR	-	-	3.2	0.6	23.3
17	0.4	-	-	-	-	-	8.6	0.4	4.6	4.0
18	1.4	-	-	-	2.0	0.2	0.4	-	2.2	0.6
19	-	-	-	0.6	TR	TR	5.0	0.8	1.0	-
20	-	1.0	-	-	-	-	-	TR	3.6	-
21	-	0.5	1.4	-	-	0.2	TR	-	-	0.7
22	-	TR	-	-	-	0.8	8.0	3.8	TR	1.2
23	-	3.4	0.5	-	-	6.6	2.6	TR	2.2	1.8
24	1.8	8.0	TR	-	-	6.8	22.0	-	13.7	-
25	TR	-	-	1.0	-	1.8	1.4	0.2	-	0.2
26	-	TR	-	-	TR	16.8	3.8	-	-	-
27	0.6	TR	-	2.4	3.0	5.2	17.0	-	14.0	
28	-	-	3.0	TR	5.6	0.2	0.8	14.0	69.5	
29	1.4	-	39.1	TR	-	0.2	0.2	2.8	-	0.2
30	TR	3.1	-	1.0	0.4	0.6	9.2	TR	TR	-
31	-		TR	1.5		-		-	3.2	
	36.6	71.5	181.8	40.9	21.8	43	131.9	69.2	194.8	55.6
	31.8	76.5	99.3			31.8	76.5	99.3	66.3	40.9

APPENDIX 4

Regression coefficients and standard errors for leaves per plant fitted to linear polynomials of the form $y = a + bt$ (1979) (tl.1 to se.o)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-4.1511			
		Time (b)	0.2781	0.0124	.98	22.36
Oro	2	Constant (a)	-3.8306			
		Time (b)	0.2651	0.0122	.98	21.69
Oro	3	Constant (a)	-3.9556			
		Time (b)	0.2831	0.0170	.96	16.63
Oro	4	Constant (a)	-4.0265			
		Time (b)	0.2910	0.0110	.98	26.53
Regent	1	Constant (a)	-3.8799			
		Time (b)	0.2502	0.0175	.95	14.29
Regent	2	Constant (a)	-3.6319			
		Time (b)	0.2385	0.0125	.97	19.05
Regent	3	Constant (a)	-3.0511			
		Time (b)	0.2295	0.0130	.97	17.62
Regent	4	Constant (a)	-3.6432			
		Time (b)	0.2575	0.0142	.97	18.11
74G-1382	1	Constant (a)	-2.6328			
		Time (b)	0.2149	0.0153	.95	14.06
74G-1382	2	Constant (a)	-3.0305			
		Time (b)	0.2261	0.0157	.95	14.43
74G-1382	3	Constant (a)	-3.1236			
		Time (b)	0.2410	0.0136	.97	17.69
74G-1382	4	Constant (a)	-2.4778			
		Time (b)	0.2220	0.0141	.96	15.74

APPENDIX 5

Regression coefficients and standard errors for leaves per plant fitted to linear polynomials of the form y = a + bt (1979) (se.o to f.1)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-2.0834			
		Time (b)	0.2228	0.0246	.85	9.05
Oro	2	Constant (a)	-2.9061			
		Time (b)	0.2442	0.0253	.87	9.66
Oro	3	Constant (a)	-2.0103			
		Time (b)	0.2306	0.0167	.93	13.80
Oro	4	Constant (a)	-2.8638			
		Time (b)	0.2556	0.0172	.94	14.85
Regent	1	Constant (a)	-1.9328			
		Time (b)	0.1961	0.0330	.75	5.95
Regent	2	Constant (a)	-1.5820			
		Time (b)	0.1847	0.0266	.80	6.95
Regent	3	Constant (a)	-1.3051			
		Time (b)	0.1916	0.0306	.77	6.26
Regent	4	Constant (a)	-0.5205			
		Time (b)	0.1773	0.0396	.62	4.48
74G-1382	1	Constant (a)	-0.9424			
		Time (b)	0.1695	0.0238	.82	7.12
74G-1382	2	Constant (a)	-0.8310			
		Time (b)	0.1709	0.0285	.76	5.99
74G-1382	3	Constant (a)	1.1805			
		Time (b)	0.1242	0.0332	.56	3.74
74G-1382	4	Constant (a)	-0.9743			
		Time (b)	0.1880	0.0219	.87	8.49

APPENDIX 6

Regression coefficients and standard errors for leaves per plant fitted to linear polynomials of the form $y = 1 + bt$ (1979) (t1.1 to f.1)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-3.3742			
		Time (b)	0.2491	0.0099	.96	25.20
Oro	2	Constant (a)	-3.5888			
		Time (b)	0.2581	0.0097	.96	26.64
Oro	3	Constant (a)	-3.2055			
		Time (b)	0.2550	0.0073	.98	34.94
Oro	4	Constant (a)	-3.4543			
		Time (b)	0.2677	0.0068	.98	39.42
Regent	1	Constatnt (a)	-3.1069			
		Time (b)	0.2216	0.0127	.93	17.49
Regent	2	Constant (a)	-2.9500			
		Time (b)	0.2142	0.0105	.95	20.48
Regent	3	Constant (a)	-2.7584			
		Time (b)	0.2227	0.0118	.94	18.94
Regent	4	Constant (a)	-2.6571			
		Time (b)	0.2233	0.0155	.90	14.42
74G-1382	1	Constant (a)	-2.1254			
		Time (b)	0.1971	0.0094	.95	20.93
74G-1382	2	Constant (a)	-2.5143			
		Time (b)	0.2097	0.0114	.94	18.37
74G-1382	3	Constant (a)	-1.8478			
		Time (b)	0.1939	0.0147	.89	13.18
74G-1382	4	Constant (a)	-2.2669			
		Time (b)	0.2177	0.0088	.96	24.64

APPENDIX 7

Regression coefficients and standard errors for leaves per plant fitted to linear polynomials of the form $y_t = a + bt$ (1980) (t1.1 to se.o)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-0.8750			
		Time (b)	0.1369	0.0267	.77	5.13
Oro	2	Constant (a)	-0.4803			
		Time (b)	0.1064	0.0256	.68	4.16
Oro	3	Constant (a)	-0.8145			
		Time (b)	0.1344	0.0277	.74	4.84
Oro	4	Constant (a)	-1.7211			
		Time (b)	0.1674	0.0373	.72	4.49
Regent	1	Constant (a)	-1.4186			
		Time (b)	0.1415	0.0152	.91	9.31
Regent	2	Constant (a)	-1.2823			
		Time (b)	0.1529	0.0113	.95	13.56
Regent	3	Constant (a)	-1.2822			
		Time (b)	0.1350	0.0197	.84	6.86
Regent	4	Constant (a)	-2.0014			
		Time (b)	0.0196	0.0133	.95	12.78
74G-1382	1	Constant (a)	-0.0804			
		Time (b)	0.0767	0.0253	.57	3.03
74G-1382	2	Constant (a)	-1.0334			
		Time (b)	0.1456	0.0133	.94	10.95
74G-1382	3	Constant (a)	0.2481			
		Time (b)	0.0710	0.0207	.63	3.42
74G-1382	4	Constant (a)	-0.5174			
		Time (b)	0.1174	0.0218	.80	5.38
75G-1999B	1	Constant (a)	-0.6772			
		Time (b)	0.1070	0.0196	.81	5.44
75G-1999B	2	Constant (a)	-0.60960			
		Time (b)	0.1222	0.0162	.89	7.53

75G-1999B	3	Constant (a)	-1.4408			
		Time (b)	0.1347	0.0194	.87	6.92
75G-1999B	4	Constant (a)	-0.9345			
		Time (b)	0.1146	0.0153	.89	7.48
75G-2180	1	Constant (a)	-0.68790			
		Time (b)	0.1110	0.0244	.75	4.54
75G-2180	2	Constant (a)	-0.3344			
		Time (b)	0.0888	0.0302	.55	2.94
75G-2180	3	Constant (a)	-0.5539			
		Time (b)	0.0986	0.0249	.69	3.96
75G-2180	4	Constant (a)	-1.5582			
		Time (b)	0.1543	.0070	.99	21.91
75G-908	1	Constant (a)	0.2201			
		Time (b)	0.0696	0.0294	.44	2.37
75G-908	2	Constant (a)	-1.3687			
		Time (b)	0.1356	0.0289	.76	4.69
75G-908	3	Constant (a)	-2.0298			
		Time (b)	0.1769	0.0224	.90	7.90
75G-908	4	Constant (a)	-0.8520			
		Time (b)	0.1324	0.0197	.87	6.72
Altex	1	Constant (a)	-0.7827			
		Time (b)	0.1243	0.0110	.94	11.27
Altex	2	Constant (a)	-0.3941			
		Time (b)	0.0983	0.0176	.80	5.58
Altex	3	Constant (a)	-0.8972			
		Time (b)	0.1161	0.0215	.78	5.40
Altex	4	Constant (a)	-0.7502			
		Time (b)	0.1078	0.0312	.60	3.45
Tower	1	Constant (a)	-2.5425			
		Time (b)	0.1702	0.0262	.84	6.49
Tower	2	Constant (a)	-1.9069			
		Time (b)	0.1394	0.0183	.88	7.60
Tower	3	Constant (a)	-2.0398			

		Time (b)	0.1553	0.0155	.93	10.01
Tower	4	Constant (a)	-1.2841			
		Time (b)	0.1181	0.0207	.80	5.71
Candle	1	Constant (a)	-0.2349			
		Time (b)	0.1676	0.0259	.82	6.48
Candle	2	Constant (a)	-0.2502			
		Time (b)	0.1793	0.0350	.74	5.12
Candle	3	Constant (a)	-0.3284			
		Time (b)	0.1984	0.0282	.85	7.03
Candle	4	Constant (a)	-0.7564			
		Time (b)	0.1821	0.0406	.69	4.48
Torch	1	Constant (a)	-2.2950			
		Time (b)	0.2663	0.0185	.96	14.41
Torch	2	Constant (a)	-1.7235			
		Time (b)	0.2433	0.0216	.93	11.28
Torch	3	Constant (a)	-1.1958			
		Time (b)	0.2166	0.0277	.87	7.83
Torch	4	Constant (a)	-1.5549			
		Time (b)	0.2376	0.0118	.98	20.12

APPENDIX 8

Regression coefficients and standard errors for leaves per plant fitted to linear polynomials of the form y = a + bt (1980) (se.o to f.1)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-1.7629			
		Time (b)	0.2351	0.0429	.70	5.48
Oro	2	Constant (a)	-4.2210			
		Time (b)	0.2928	0.0422	.79	6.93
Oro	3	Constant (a)	-2.9862			
		Time (b)	0.2667	0.0418	.76	6.37
Oro	4	Constant (a)	-3.5806			
		Time (b)	0.2847	0.0363	.82	7.84
Regent	1	Constant (a)	-2.9270			
		Time (b)	0.2431	0.0515	.67	4.72
Regent	2	Constant (a)	-1,3129			
		Time (b)	0.1958	0.0402	.68	4.87
Regent	3	Constant (a)	-4.3727			
		Time (b)	0.2632	0.0450	.76	5.85
Regent	4	Constant (a)	-0.5158			
		Time (b)	0.1858	0.0704	.39	2.64
74G-1382	1	Constant (a)	-4.7364			
		Time (b)	0.2570	0.0460	.72	5.58
74G-1382	2	Constant (a)	-0.9152			
		Time (b)	0.1683	0.0369	.63	4.56
74G-1382	3	Constant (a)	--1.8913			
		Time (b)	0.1814	0.0357	.68	5.08
74G-1382	4	Constant (a)	-1.3985			
		Time (b)	0.1759	0.0363	.66	4.84
75G-1999B	1	Constant (a)	-1.5078			
		Time (b)	0.1748	0.0638	.40	2.74
75G-1999B	2	Constant (a)	-3.3305			
		Time (b)	0.2238	0.0429	.71	5.22

75G-1999B	3	Constant (a)	-3.5661			
		Time (b)	0.2396	0.0468	.70	5.12
75G-1999B	4	Constant (a)	-4.2772			
		Time (b)	0.2546	0.0450	.74	5.66
75G-2180	1	Constant (a)	-3.0466			
		Time (b)	0.2268	0.0416	.71	5.45
75G-2180	2	Constant (a)	-4.4901			
		Time (b)	0.2554	0.0447	.73	5.71
75G-2180	3	Constant (a)	-3.5476			
		Time (b)	0.2455	0.0485	.68	5.06
75G-2180	4	Constant (a)	-3.1839			
		Time (b)	0.2345	0.0439	.70	5.34
75G-908	1	Constant (a)	-3.4449			
		Time (b)	0.2338	0.0624	.56	3.74
75G-908	2	Constant (a)	-5.7188			
		Time (b)	0.3077	0.0517	.76	5.95
75G-908	3	Constant (a)	-3.4661			
		Time (b)	0.2538	0.0586	.63	4.33
75G-908	4	Constant (a)	-3.0120			
		Time (b)	0.2362	0.0381	.78	6.19
Altex	1	Constant (a)	-2.0623			
		Time (b)	0.2104	0.0494	.62	4.26
Altex	2	Constant (a)	-2.1240			
		Time (b)	0.2062	0.0483	.62	4.27
Altex	3	Constant (a)	-2.8720			
		Time (b)	0.2349	0.0543	.63	4.33
Altex	4	Constant (a)	-1.2845			
		Time (b)	0.1892	0.0734	.38	2.58
Tower	1	Constant (a)	-1.6561			
		Time (b)	0.1996	0.0419	.67	4.76
Tower	2	Constant (a)	-4.9787			
		Time (b)	0.2723	0.0385	.82	7.07
Tower	3	Constant (a)	-3.4646			

		Time (b)	0.2241	0.0519	.63	4.32
Tower	4	Constant (a)	-5.0773			
		Time (b)	0.2714	0.0462	.76	5.87
Candle	1	Constant (a)	-4.1200			
		Time (b)	0.3364	0.0992	.62	3.39
Candle	2	Constant (a)	-1.4203			
		Time (b)	0.2568	0.967	.50	2.65
Candle	3	Constant (a)	-0.8335			
		Time (b)	0.2439	0.0847	.54	2.88
Candle	4	Constant (a)	-2.2812			
		Time (b)	0.2636	0.1081	.46	2.44
Torch	1	Constant (a)	-2.5711			
		Time (b)	0.2963	0.0959	.58	3.09
Torch	2	Constant (a)	-3.0073			
		Time (b)	0.3119	0.1012	.58	3.08
Torch	3	Constant (a)	-1.4933			
		Time (b)	0.2652	0.0962	.52	2.76
Torch	4	Constant (a)	-2.0390			
		Time (b)	0.2778	0.1021	.51	2.72

APPENDIX 9

Regression coefficients and standard errors for leaves per plant fitted to linear polynomials of the form $y = a + bt$ (1980) (tl.1 to f.1)

Genotype	Replicate		Coefficient	S.E.	r^2	t value.
Oro	1	Constant (a)	-3.1241			
		Time (b)	0.2617	0.0213	.88	12.28
Oro	2	Constant (a)	-3.9424			
		Time (b)	0.2851	0.0204	.90	13.97
Oro	3	Constant (a)	-3.4868			
		Time (b)	0.2753	0.0206	.89	13.33
Oro	4	Constant (a)	-4.1706			
		Time (b)	0.2949	0.0190	.92	15.54
Regent	1	Constant (a)	-3.6562			
		Time (b)	0.2565	0.0203	.89	12.63
Regent	2	Constant (a)	-2.5467			
		Time (b)	0.2207	0.059	.91	13.89
Regent	3	Constant (a)	-3.4896			
		Time (b)	0.2421	0.0175	.90	13.82
Regent	4	Constant (a)	-3.2023			
		Time (b)	0.2421	0.0268	.80	9.02
74G-1382	1	Constant (a)	-2.7866			
		Time (b)	0.2114	0.0216	.83	9.79
74G-1382	2	Constant (a)	-1.6302			
		Time (b)	0.845	0.0166	.87	11.08
74G-1382	3	Constant (a)	-1.6457			
		Time (b)	0.1752	0.0161	.86	10.90
74G-1382	4	Constant (a)	-1.6421			
		Time (b)	0.1811	0.0164	.86	11.06
75G-1999B	1	Constant (a)	-2.2047			
		Time (b)	0.1891	0.0250	.75	7.55
75G-1999B	2	Constant (a)	-2.2756			
		Time (b)	0.1986	0.0173	.87	11.50

75G-1999B	3	Constant (a)	-3.3440			
		Time (b)	0.2332	0.0188	.89	12.41
75G-1999B	4	Constant (a)	-3.2396			
		Time (b)	0.2293	0.0185	.89	12.363
75G-2180	1	Constant (a)	-2.7110			
		Time (b)	0.2178	0.0195	.87	11.19
75G-2180	2	Constant (a)	-2.9779			
		Time (b)	0.2195	0.0211	.85	10.40
75G-2180	3	Constant (a)	-3.1332			
		Time (b)	0.2346	0.0227	.85	10.34
75G-2180	4	Constant (a)	-2.9635			
		Time (b)	0.2287	0.0197	.88	11.63
75G-908	1	Constant (a)	-2.4086			
		Time (b)	0.2080	0.0265	.77	7.85
75G-908	2	Constant (a)	-3.9217			
		Time (b)	0.2635	0.0232	.88	11.36
75G-908	3	Constant (a)	-3.4128			
		Time (b)	0.2515	0.0247	.85	10.18
75G-908	4	Constant (a)	-2.6034			
		Time (b)	0.2256	0.0165	.91	13.66
Altex	1	Constant (a)	-2.5864			
		Time (b)	0.2208	0.0198	.87	11.13
Altex	2	Constant (a)	-2.6012			
		Time (b)	0.2151	0.020	.86	10.65
Altex	3	Constant (a)	-3.2313			
		Time (b)	0.2414	0.0219	.86	11.03
Altex	4	Constant (a)	-2.7536			
		Time (b)	0.2208	0.0295	.75	7.49
Tower	1	Constant (a)	-3.9805			
		Time (b)	0.2477	0.0197	.89	12.57
Tower	2	Constant (a)	-4.5212			
		Time (b)	0.2608	0.0169	.92	15.40
Tower	3	Constant (a)	-3.5115			

		Time (b)	0.2240	0.0211	.86	10.63
Tower	4	Constant (a)	-4.1792			
		Time (b)	0.2501	0.0201	.89	12.44
Candle	1	Constant (a)	-2.8714			
		Time (b)	0.3004	0.0274	.88	10.95
Candle	2	Constant (a)	-1.9443			
		Time (b)	0.2665	0.0278	.85	9.56
Candle	3	Constant (a)	-1.4621			
		Time (b)	0.2570	0.0231	.89	11.14
Candle	4	Constant (a)	-2.3001			
		Time (b)	0.2630	0.0274	.85	9.58
Torch	1	Constant (a)	-3.0751			
		Time (b)	0.3064	0.0236	.91	12.99
Torch	2	Constant (a)	-3.0472			
		Time (b)	0.3097	0.0259	.90	11.95
Torch	3	Constant (a)	-2.5861			
		Time (b)	0.2888	0.0260	.88	11.09
Torch	4	Constant (a)	-2.5192			
		Time (b)	0.2873	0.0248	.89	11.58

APPENDIX 10

Regression coefficients and standard errors for dry weight fitted to cubic polynomials of the form log(e) DW = $a + bt + ct^2 + dt^3$ (1979)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-1.0220		.93	4.78
		Time (b)	5.3549	7.0722		
		Time^2 (c)	-5.9584	1.0225		
		Time (b)	2.2191	4.6461		
Oro	2	Constant (a)	-9.4155		.95	6.12
		Time (b)	5.1803	5.7404		
		Time^2 (c)	-5.9601	8.2994		
		Time^3 (d)	2.3078	3.7711		
Oro	3	Constant (a)	-6.0346		.91	4.31
		Time (b)	3.9938	6.0838		
		Time^2 (c)	-4.5166	8.7960		
		Time^3 (d)	1.7227	3.9968		
Oro	4	Constant (a)	-7.6269		.83	3.46
		Time (b)	4.6838	9.1599		
		Time^2 (c)	-5.4071	1.3243		
		Time^3 (d)	2.0801	60176		
Regent	1	Constant (a)	-6.4610		.88	3.02
		Time (b)	4.1267	8.2920		
		Time^2 (c)	-4.6298	1.2302		
		Time^3 (d)	1.7346	5.7478		
Regent	2	Constant (a)	-1.4809		.86	3.98
		Time (b)	7.4028	1.257		
		Time^2 (c)	-8.8102	1.8650		
		Time^3 (d)	3.4661	8.7145		
Regent	3	Constant (a)	-6.6180		.88	3.84
		Time (b)	4.4094	7.6482		
		Time^2 (c)	-5.1950	1.1346		
		Time^3 (d)	2.0382	5.3016		
Regent	4	Constant (a)	-4.3077		.88	3.42
		Time (b)	3.5162	6.6731		
		Time^2 (c)	-4.0600	9.8992		
		Time^3 (d)	1.5801	4.6256		
74G-1382	1	Constant (a)	-1.1129		.97	5.79
		Time (b)	5.8960	6.3524		

		Time' (c)	-6.9629	9.8072		
		Time' (d)	2.7726	4.7863		
74G-1382	2	Constant (a)	-7.8757		.93	3.49
		Time (b)	4.6482	8.3331		
		Time' (c)	-5.4570	1.2865		
		Time' (d)	2.1940	6.2787		
74G-1382	3	Constant (a)	-8.5574		.90	3.00
		Time (b)	4.9790	1.0441		
		Time' (c)	-5.8827	1.6120		
		Time' (d)	2.3595	7.8672		
74G-1382	4	Constant (a)	-8.8032		.91	4.78
		Time (b)	5.4676	8.1049		
		Time' (c)	-6.9111	1.2513		
		Time' (d)	2.9226	6.1067		

APPENDIX 11

Regression coefficients and standard errors for dry weight fitted to quadratic polynomials of the form log (e) DW = $a + bt + ct^2$ (1980)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-3.7646			
		Time (b)	0.2147	0.0140		
		Time^2 (c)	-0.0012	0.0001	.95	10.88
Oro	2	Constant (a)	-3.4341			
		Time (b)	0.2100	0.0185		
		Time^2 (c)	-0.0011	0.0001	.91	8.12
Oro	3	Constant (a)	-2.2902			
		Time (b)	0.1754	0.0117		
		Time^2 (c)	-0.0009	0.0001	.95	10.33
Oro	4	Constant (a)	-3.8092			
		Time (b)	0.2166	0.0175		
		Time^2 (c)	-0.0012	0.0001	.92	8.87
Regent	1	Constant (a)	-5.3454			
		Time (b)	0.2573	0.0159		
		Time^2 (c)	-0.0014	0.0001	.95	11.5
Regent	2	Constant (a)	-3.6737			
		Time (b)	0.2146	0.0127		
		Time^2 (c)	-0.0012	0.0001	.96	11.98
Regent	3	Constant (a)	-3.7289			
		Time (b)	0.2174	0.0168		
		Time^2 (c)	-0.0012	0.0001	.93	9.34
Regent	4	Constant (a)	-5.1715			
		Time (b)	0.2464	0.0164		
		Time^2 (c)	-0.0014	0.0001	.95	10.59
74G-1382	1	Constant (a)	-5.1464			
		Time (b)	0.2422	0.0178		
		Time^2 (c)	-0.0013	0.0001	.95	9.24
74G-1382	2	Constant (a)	-3.6476			
		Time (b)	0.2222	0.0127		
		Time^2 (c)	-0.0013	0.0001	.96	12.53
74G-1382	3	Constant (a)	-4.5194			
		Time (b)	0.2412	0.0180		

		Time^2 (c)	-0.0014	0.0001	.93	9.68
74G-1382	4	Constant (a)	-3.8569			
		Time (b)	0.2231	0.0152		
		Time^2 (c)	-0.0013	0.0001	.95	10.49
75G-1999B	1	Constant (a)	-3.7341			
		Time (b)	0.2166	0.0173		
		Time^2 (c)	-0.0012	0.0001	.94	8.66
75G-1999B	2	Constant (a)	-2.6266			
		Time (b)	0.1860	0.0149		
		Time^2 (c)	-0.0010	0.0001	.94	8.43
75G-1999B	3	Constant (a)	-3.9411			
		Time (b)	0.2288	0.0144		
		Time^2 (c)	-0.0013	0.0001	.95	11.46
75G-1999B	4	Constant (a)	-4.1027			
		Time (b)	0.2330	0.0152		
		Time^2 (c)	-0.0013	0.0001	.95	10.74
75G-2180	1	Constant (a)	-3.5529			
		Time (b)	0.2156	0.0169		
		Time^2 (c)	-0.0012	0.0001	.94	8.85
75G-2180	2	Constant (a)	-3.8876			
		Time (b)	0.2236	0.0122		
		Time^2 (c)	-0.0013	0.0001	.97	12.74
75G-2180	3	Constant (a)	-3.2812			
		Time (b)	0.1958	0.0189		
		Time^2 (c)	-0.0010	0.0002	.92	6.92
75G-2180	4	Constant (a)	-4.3620			
		Time (b)	0.2449	0.0209		
		Time^2 (c)	-0.0015	0.0002	.91	8.64
75G-0908	1	Constant (a)	-4.1669			
		Time (b)	0.2229	0.0140		
		Time^2 (c)	-0.0012	0.0001	.96	11.02
75G-908	2	Constant (a)	-5.0633			
		Time (b)	0.2450	0.0188		
		Time^2 (c)	-0.0014	0.0001	.94	8.88
75G-908	3	Constant (a)	-4.6123			
		Time (b)	0.2323	0.0179		

		Time' (c)	-0.0013	0.0001	.94	9.03
75G-908	4	Constant (a)	-3.9958			
		Time (b)	0.2324	0.0116		
		Time' (c)	-0.0014	0.0001	.97	14.38
Altex	1	Constant (a)	-3.7519			
		Time (b)	0.2197	0.0151		
		Time' (c)	-0.0012	0.0001	.95	10.15
Altex	2	Constant (a)	-4.6582			
		Time (b)	0.2494	0.0181		
		Time' (c)	-0.0015	0.0001	.94	10.02
Altex	3	Constant (a)	-3.8446]			
		Time (b)	0.2254	0.0160		
		Time' (c)	-0.0013	0.0001	.94	10.13
Altex	4	Constant (a)	-4.6724			
		Time (b)	0.2513	0.0143		
		Time' (c)	-0.0015	0.0001	.96	12.72
Tower	1	Constant (a)	-4.8396			
		Time (b)	0.2359	0.0198		
		Time' (c)	-0.0013	0.0002	.92	8.31
Tower	2	Constant (a)	-4.6101			
		Time (b)	0.2366	0.0179		
		Time' (c)	-0.0013	0.0001	.93	9.37
Tower	3	Constant (a)	-4.1180			
		Time (b)	0.2175	0.0156		
		Time' (c)	-0.0012	0.0001	.94	9.68
Tower	4	Constant (a)	-4.7984			
		Time (b)	0.2390	0.0159		
		Time' (c)	-0.0013	0.0001	.95	10.61
Candle	1	Constant (a)	-3.1835			
		Time (b)	0.2012	0.0218		
		Time' (c)	-0.0012	0.0002	.91	6.14
Candle	2	Constant (a)	-2.8112			
		Time (b)	0.2014	0.0162		
		Time' (c)	-0.0012	0.0001	.94	8.62
Candle	3	Constant (a)	-2.9645			
		Time (b)	0.1994	0.0204		

		Time' (c)	-0.0012	0.0002	.91	6.61
Candle	4	Constant (a)	-4.7558			
		Time (b)	0.2583	0.0188		
		Time' (c)	-0.0016	0.0002	.95	9.63
Torch	1	Constant (a)	-4.6174			
		Time (b)	0.2649	0.0203		
		Time' (c)	-0.0017	0.0002	.94	9.42
Torch	2	Constant (a)	-4.0316			
		Time (b)	012329	0.0281		
		Time' (c)	-0.0014	0.0002	.88	5.72
Torch	3	Constant (a)	-3.4517			
		Time (b)	0.2284	0.0158		
		Time' (c)	-0.0014	0.0001	.95	10.19
Torch	4	Constant (a)	-3.3337			
		Time (b)	0.2239	0.0104		
		Time' (c)	-0.0014	0.0001	.98	15.08

APPENDIX 12

Regression coefficients and standard errors for total leaf area fitted to quadratic polynomials of the form $y = a + bt + ct^2$ (1979)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-38324.0002			
		Time (b)	1569.0619	191.3336		
		Time^2 (c)	-11.1839	1.2956	.66	8.63
Oro	2	Constant (a)	-22954.0051			
		Time (b)	1065.2492	169.2229		
		Time^2 (c)	-7.8450	1.1459	.59	6.85
Oro	3	Constant (a)	-28196.4238			
		Time (b)	1334.5638	177.1867		
		Time^2 (c)	-9.8713	1.1998	.68	8.23
Oro	4	Constant (a)	-38505.1236			
		Time (b)	1710.7003	338.5346		
		Time^2 (c)	-12.5145	2.2924	.47	5.46
Regent	1	Constant (a)	-28227.2830			
		Time (b)	1320.3379	158.7933		
		Time^2 (c)	-9.9787	1.1061	.72	9.02
Regent	2	Constant (a)	-27960.6486			
		Time (b)	1254.5460	157.0578		
		Time^2 (c)	-9.3385	1.0940	.68	8.54
Regent	3	Constant (a)	-27555.7400			
		Time (b)	1342.6233	196.1064		
		Time^2 (c)	-10.1974	1.3660	.64	7.46
Regent	4	Constant (a)	-23292.0950			
		Time (b)	1230.9122	179.4807		
		Time^2 (c)	-9.4711	1.2502	.67	7.48
74G-1382	1	Constant (a)	-34689.1257			
		Time (b)	1437.4295	184.1551		
		Time^2 (c)	-10.8642	1.3402	.66	8.11
74G-1382	2	Constant (a)	-21003.6645			
		Time (b)	956.7537	142.0698		
		Time^2 (c)	-7.2517	1.0340	.59	7.01
74G-1382	3	Constant (a)	-27592.7636			
		Time (b)	1227.6014	141.2444		

		Time^2 (c)	-9.3445	1.0279	.71	9.09
74G-1382	4	Constant (a)	-18043.6099			
		Time (b)	925.1427	139.4648		
		Time^2 (c)	-7.2975	1.0150	.64	7.19

APPENDIX 13

Regression coefficients and standard errors for total leaf area fitted to quadratic polymomials of the form $y = a + bt + ct^2$ (1980)

Genotype	Replicate		Coefficient	S.E.	r^2	t value
Oro	1	Constant (a)	-25080.2844			
		Time (b)	1441.5077	210.7244		
		Time² (c)	-11.0210	1.6569	.59	6.65
Oro	2	Constant (a)	-21001.8924			
		Time (b)	1272.4570	188.1428		
		Time² (c)	-9.9187	1.4794	.58	6.70
Oro	3	Constant (a)	-18662.6924			
		Time (b)	1158.2745	154.9352		
		Time² (c)	-9.0460	1.2183	.63	7.42
Oro	4	Constant (a)	-20863.8705	1182.9422	146.3166	
		Time² (c)	-8.9204	1.1505	.67	7.75
Regent	1	Constant (a)	-18182.9550			
		Time (b)	987.8198	133.6794		
		Time² (c)	-7.3614	1.0843	.65	6.79
Regent	2	Constant (a)	-20073.3191			
		Time (b)	1155.5093	150.8513		
		Time² (c)	-8.9978	1.2235	.65	7.35
Regent	3	Constant (a)	-24534.1170			
		Time (b)	1426.9138	182.9418		
		Time² (c)	-11.1575	1.4838	.66	7.52
Regent	4	Constant (a)	-17225.2644			
		Time (b)	928.2077	163.0803		
		Time² (c)	-6.9098	1.3227	.52	5.22
74G-1382	1	Constant (a)	-19419,6323			
		Time (b)	1058.2065	162.0057		
		Time² (c)	-8.0966	1.3569	.60	5.97
74G-1382	2	Constant (a)	-22667.6308			
		Time (b)	1327.1557	247.8195		
		Time² (c)	-10.8743	2.0757	.48	5.24
74G-1382	3	Constant (a)	-14045.3380			
		Time (b)	846.6322	104.6842		

		Time' (c)	-6.8950	0.8768	.68	7.86
74G-1382	4	Constant (a)	-161065.0544			
		Time (b)	959.0571	107.7197		
		Time' (c)	-7.8214	0.9022	.72	8.6688
75G-19998	1	Constant (a)	-22401.1746			
		Time (b)	1269.9657	214.7314		
		Time' (c)	-9.6495	1.7986	.56	5.36
75G-19998	2	Constant (a)	-27758.4308			
		Time (b)	1594.8809	356.9936		
		Time' (c)	-12.6973	2.9901	.40	4.25
75G-19998	3	Constant (a)	-19587.7048			
		Time (b)	1159.4941	194.4006]		
		Time' (c)	-9.4267	1.6283	.53	5.79
75G-19998	4	Constant (a)	-22059.4462			
		Time (b)	1283.9456	174.3957		
		Time' (c)	-10.2837	1.4607	.64	7.04
74G-2180	1	Constant (a)	-28326.9628			
		Time (b)	1622.6816	204.6810		
		Time' (c)	-12.9845	1.7144	.67	7.57
75G-2180	2	Constant (a)	-30489.0407			
		Time (b)	1717.1960	279.0975		
		Time' (c)	- 13.5768	2.3377	.56	5.81
75G-2180	3	Constant (a)	-18626.4768			
		Time (b)	1082.3183	169.1653		
		Time' (c)	-8.7596	1.4169	.57	6.18
75G-2180	4	Constant (a)	-22817.0559			
		Time (b)	1334.1668	220.9551		
		Time' (c)	-10.7307	1.8507	.54	5.80
75G-908	1	Constant (a)	-19122.6613			
		Time (b)	1096.0218	204.1174		
		Time' (c)	-8.6882	1.7097	.49	5.08
75G-908	2	Constant (a)	-18207.8936			
		Time (b)	1008.973	217.1836		
		Time' (c)	-7.8128	1.8191	.42	4.29
75G-908	3	Constant (a)	-23553.7383			
		Time (b)	1268.8775	263.5275		

		Time' (c)	-9.9102	2.2073	.44	4.49
75G-908	4	Constant (a)	-20738.7930			
		Time (b)	1252.237	180.2706		
		Time' (c)	-10.3165	1.5099	.61	6.83
Altex	1	Constant (a)	-22920.1780			
		Time (b)	1324.4550	165.4283		
		Time' (c)	-10.5967	1.3856	.68	7.65
Altex		Constant (a)	-18460.7223			
		Time (b)	1117.6409	146.4183		
		Time' (c)	-8.8877	1.2264	.66	7.25
Altex	3	Constant (a)	-20893.0693			
		Time (b)	1243.3788	210.0648		
		Time' (c)	-10.1135	1.7595	.53	5.75
Altex	4	Constant (a)	-24324.9178			
		Time (b)	1359.0939	194.3959		
		Time' (c)	-10.6253	1.6282	.62	6.52
Tower	1	Constant (a)	-27548.3572			
		Time (b)	1540.1967	285.1278		
		Time' (c)	-12.0036	2.3126	.48	5.19
Tower	2	Constant (a)	-29132.3140			
		Time (b)	1604.0077	268.5604		
		Time' (c)	-12.3465	2.1783	.53	5.67
Tower	3	Constant (a)	-16543.6484			
		Time (b)	962.2452	152.5542		
		Time' (c)	-7.4280	1.2374	.56	6.00
Tower	4	Constant (a)	-23140.8794			
		Time (b)	1299.0621	217.0440		
		Time' (c)	-10.0790	1.7604	.53	5.72
Candle	1	Constant (a)	-16323.6352			
		Time (b)	1016.2304	321.7918		
		Time' (c)	-9.1730	2.9914	.26	3.06
Candle	2	Constant (a)	-23081.8564			
		Time (b)	1398.3137	427.0311		
		Time' (c)	-12.5664	3.9696	.28	3.16
Candle	3	Constant (a)	-12317.9174			
		Time (b)	810.3570	170.7448		

		Time' (c)	-7.4264	1.5872	.45	4.68
Candle	4	Constant (a)	-15484.8616			
		Time (b)	958.3976	228.8244		
		Time' (c)	-8.5963	2.1271	.39	4.04
Torch	1	Constant (a)	-18804.5714			
		Time (b)	1170.727	276.1998		
		Time' (c)	-10.4683	2.5675	.39	4.08
Torch	2	Constant (a)	-14410.2602			
		Time (b)	887.6701	142.8391		
		Time' (c)	-7.9222	1.3278	.58	5.97
Torch	3	Constant (a)	-18593.6432			
		Time (b)	1188.1547	296.3329		
		Time' (c)	-10.8343	2.7547	.36	3.93
Torch	4	Constant (a)	-12471.2519			
		Time (b)	828.3960	135.8442		
		Time' (c)	-7.6268	1.2628	.57	6.04

APPENDIX 14

Regression coefficients and standard errors for axillary branch leaf area fitted to quadratic polynomials of the form $y = a + bt + ct^2$ (1980).

Genotype Replciate		Coefficient	S.E.	r^2	t value	
Oro	1	Constant (a)	-15014.3744			
		Time (b)	463.4349	112.2847		
		Time^2 (c)	-2.8852	0.7582	.54	3.80
Oro	2	Constant (a)	-10221.9288			
		Time (b)	307.7147	80.9421		
		Time^2 (c)	-1.7651	0.5466	.64	3.23
Oro	3	Constant (a)	-10448.7730			
		Time (b)	312.4638	113.0448		
		Time^2 (c)	-1.8274	0.7634	.45	2.39
Oro	4	Constant (a)	-13150.4514			
		Time (b)	402.6296	117.3344		
		Time^2 (c)	-2.4736	0.7923	.47	3.12
Regent	1	Constant (a)	-23431.6306			
		Time (b)	748.9293	109.3590		
		Time^2 (c)	-4.7905	0.7583	.78	6.32
Regent	2	Constant (a)	-17487.3307			
		Time (b)	560.6174	129.7937		
		Time^2 (c)	-3.6175	0.9000	.57	4.02
Regent	3	Constant (a)	-19301.9538			
		Time (b)	603.4677	185.9482		
		Time^2 (c)	-3.7380	1.2894	.49	2.90
Regent	4	Constant (a)	-19141.2010			
		Time (b)	611.4619	154.0340		
		Time^2 (c)	-3.8396	1.0681	.57	3.59
74G-1382	1	Constant (a)	-24649.2114			
		Time (b)	829.3198	170.0298		
		Time^2 (c)	-5.4775	1.2115	.65	4.52
74G-1382	2	Constant (a)	-27474.3082			
		Time (b)	922.5309	273.9086		
		Time^2 (c)	-6.4600	1.9516	.40	3.31
74G-1382	3	Constant (a)	-18892.4161			
		Time (b)	638.0594	120.3501		

		Time' (c)	-4.4083	0.8575	.63	5.14
74G-1382	4	Constant (a)	-20780.3783			
		Time (b)	697.0264	95.3388		
		Time' (c)	-4.8207	0.6793	.76	7.10
75G-1999B	1	Constant (a)	-37151.2319			
		Time (b)	1191.5429	268.1915		
		Time' (c)	-7.7786	1.9109	.62	4.07
75G-1999B	2	Constant (a)	-5251.0875			
		Time (b)	512.4951	114.3792		
		Time' (c)	-3.3860	0.8150	.61	4.15
75G-1999B	3	Constant (a)	-19030.0467			
		Time (b)	625.0193	120.8015		
		Time' (c)	-4.2376	0.8607	.64	4.92
75G-1999B	4	Constant (a)	-17081.7535			
		Time (b)	617.7760	239.3110		
		Time' (c)	-4.2463	1.7051	.29	2.49
75G-2180	1	Constant (a)	-36930.1412			
		Time (b)	1205.9548	208.5138		
		Time' (c)	-8.0995	1.4857	.70	5.45
75G-2180	2	Constant (a)	-46281.6481			
		Time (b)	1533.6122	506.8059		
		Time' (c)	-10.3427	3.6111	.38	2.86
75G-2180	3	Constant (a)	-21587.9541			
		Time (b)	727.3207	102.0544		
		Time' (c)	-5.0611	0.7272	.75	6.96
75G-2180	4	Constant (a)	-23910.2017			
		Time (b)	804.5114	284.2542		
		Time' (c)	-5.3476	2.0254	.37	2.64
75G-908	1	Constant (a)	-26609.782			
		Time (b)	871.7698	369.2374		
		Time' (c)	-5.8068	2.6309	.29	2.21
75G-908	2	Constant (a)	-30623.6670			
		Time (b)	1007.2137	289.2270		
		Time' (c)	-6.7924	2.0608	.45	3.30
75G-908	3	Constant (a)	-42941.6275			
		Time (b)	1401.7276	358.6284		

		Time' (c)	-9.5989	2.5553	.49	3.6
75G-908	4	Constant (a)	-19030.8027			
		Time (b)	659.5236	129.0753		
		Time' (c)	-4.5802	0.9197	.61	4.98
Altex	1	Constant (a)	-29916.2631			
		Time (b)	978.5265	174.1414		
		Time' (c)	-6.5414	1.2408	.69	5.27
Altex	2	Constant (a)	-21826.2575			
		Time (b)	694.3826	108.4190		
		Time' (c)	-4.3254	0.7725	.83	5.60
Altex	3	Constant (a)	-22831.8841			
		Time (b)	741.3129	315.9635		
		Time' (c)	-4.9063	2.2513	.30	2.18
altex	4	Constant (a)	-40267.7190			
		Time (b)	1321.8524	207.4672		
		Time' (c)	-8.9482	1.4782	.73	6.05
Tower	1	Constant (a)	-27807.4993			
		Time (b)	895.8462	136.0551		
		Time' (c)	-5.8857	0.9434	.73	6.24
Tower	2	Constant (a)	-29582.5813			
		Time (b)	964.7322	298.0395		
		Time' (c)	-6.3124	2.0667	.40	3.05
Tower	3	Constant (a)	-22882.6496			
		Time (b)	733.4445	202.6716		
		Time' (c)	-4.6972	1.4054	.49	3.34
Tower	4	Constant (a)	-18928.2024			
		Time (b)	643.2320	131.1917		
		Time' (c)	-4.3014	0.9097	.58	4.73
Candle	1	Constant (a)	-24485.8184			
		Time (b)	946.9508	351.6161		
		Time' (c)	-7.4760	2.7294	.35	2.74
Candle	2	Constant (a)	-27382.2950			
		Time (b)	1004.2905	286.2304		
		Time' (c)	-7.8136	2.2218	.47	3.52
Candle	3	Constant (a)	-16042.4557			
		Time (b)	626.2129	104.9102		

		Time^2 (c)	-5.1096	0.8144	.74	6.16
Candle	4	Constant (a)	-28911.2318			
		Time (b)	1069.3116	470.3797		
		Time^2 (c)	-8.3163	3.6513	.27	2.28
Torch	1	Constant (a)	-54766.6880			
		Time (b)	1945.2556	750.9713		
		Time^2 (c)	-15.0086	5.8293	.32	2.57
Torch	2	Constant (a)	-24530.8177			
		Time (b)	883.4154	228.3994		
		Time^2 (c)	-6.6630	1.7729	.53	3.76
Torch	3	Constant (a)	-20175.8792			
		Time (b)	706.3812	156.6456		
		Time^2 (c)	-5.2681	1.2159	.62	4.33
Torch	4	Constant (a)	-13733.4519			
		Time (b)	502.3320	144.5108		
		Time^2 (c)	-3.8141	1.1217	.47	3.40